Vol. 32, No. 1 January, 1935

THE
PSYCHOLOGICAL BULLETIN

JAMES MARK BALDWIN

(COLUMBIA, S. C., 1861—PARIS, FRANCE, 1934)

With the death of James Mark Baldwin on November 8th American Psychology lost a scholar, who by his teaching, editing, writing, and laboratory building, has been intimately connected with and influential upon its early development.

Before moving to Europe Professor Baldwin spent 27 years teaching at various universities in the United States, Mexico, and Canada. He began his career in 1886 at Princeton as Instructor of French and German. The next two years (1887–1889) he occupied the chair of Philosophy at Lake Forest. From 1889 to 1893 he was Professor of Philosophy at the University of Toronto, where he established a psychological laboratory—probably the first on British soil. Moving back to Princeton as Professor of Psychology, where he remained for ten years (1893–1903), he set up another laboratory. The next six years (1903–1909) found him occupying the double chair of Philosophy and Psychology at Johns Hopkins and here he organized his third laboratory, later developed by others. From Hopkins, Baldwin moved to the National University of Mexico (1909–1913).

The excellence of Baldwin as a teacher, his strikingly clear lectures, his thoughtfulness and generosity—and more important, his energetic capacity to inspire his students—have been attested to by a no less worthy and admiring student than the late Professor H. C. Warren.

The active professional life of Baldwin coincided with the rapidly expanding development of psychology in America. It was characteristic of the man that he participated very actively in that development. Not only did he open up opportunities for experimental work at various universities, but he was also identified with the American

Psychological Association from its inception. Baldwin served on the first council of the Association and was its sixth president (1897).

As an editor he gave much of his time and thought to various psychological publications, first as assistant to Hall on the *American Journal of Psychology,* and later to what are now the A.P.A. publications, many of which he established in coöperation with Professor Cattell. In helping to found the *Psychological Review* in 1894 and later its daughter journals—the *Index, Monograph Supplements,* and *Bulletin*—Baldwin placed all the earlier psychologists in his deep debt. Nor can we overlook his editorial work on that monumental enterprise—the *Dictionary of Psychology and Philosophy*—published in four volumes (1901–1906). In connection with the *Dictionary,* Baldwin guided the work of over 60 collaborators in an attempt to bring order and common understanding into the maze of philosophical and psychological terms.

The precocity, brilliance, and wide interests of Baldwin are excellently reflected in his writings. His publishing career began at the early age of twenty-four—just one year after obtaining his A.B., at Princeton—when he translated Ribot's volume on German Psychology (1885). Four years later—the year of his Princeton Ph.D.—appeared the first volume of his *Handbook of Psychology,* which was followed in 1891 by the second. Older students of psychology will recall that the two volumes were regarded as being in the nature of competitors to the brilliant *Principles* of William James. The catholicity of Baldwin's interests is suggested by the contents of his books, which range from Experimental Psychology (*Fragments in Philosophy and Science,* 1902); History of Psychology (*Story of the Mind,* 1902, *History of Psychology,* 2 vols., 1913); Social Psychology (*Social and Ethical Interpretations in Mental Development,* 1898, *The Individual and Society,* 1910); Child and Race Psychology (*Mental Development in the Child and Race,* 1894); Genetic Psychology and Evolution (*Development and Evolution,* 1902, *Darwin and the Humanists,* 1909), to Logic and Philosophical Interpretation (*Genetic Logic,* 3 vols., 1906–1911, of which the fourth in the series is entitled *Genetic Theory of Reality,* 1915).

As the titles indicate, the developmental conception of phenomena was always uppermost in Baldwin's theory. Undoubtedly this view has led to his most lasting psychological contribution—namely, the principles of social psychology, which include his conception of the circular reaction and the basis it lays for the development of the

social personality and its differentiation from the other personalities constituting the psychological and social community. The industry of the man is suggested by the fact that all of his work was crowded into a period of 30 years, in which academic, administrative, teaching, experimental work, and participation in practical affairs occupied much time. As Baldwin himself hints in his autobiography, were it not for his absorption in the stirring events of the war, which drew him into comparative national and political studies, he undoubtedly would have produced many more studies in psychology and philosophy. As it is, Baldwin's record of scientific publications is correlated with a series of political writings, published between the years 1914 and 1926 (*French and American Ideals,* 1914; *The Super-State,* 1916; *France and the War,* 1915; *American Neutrality,* 1916; and *Between Two Wars,* 1926).

James Mark Baldwin was one of those rare individuals whose record of work and achievements stands so clear as to make it unnecessary to embroider upon his strength as psychologist or scholar. Though his absence from America for so many years may have kept him from being better known to the younger psychologists, his place in American psychology is none the less secure.

J. R. KANTOR.

Indiana University.

CHRONAXIE [1]

BY M. O. WILSON
University of Oklahoma

Introduction

Anatomists have been interested in the spatial qualities of mind since before the time of Christ. First of all, it has been alleged that mind resides in the physical body—that the body is the developing place or 'seat' of the mind. Furthermore, the existence of certain spatial relations between mind and the nervous system has been claimed. Pythagoras and Plato held that the brain was the seat of the mind and intellect. According to Erasistratus, sensations were mediated by membranes of the brain and movement by brain tissue. Magnus ascribed judgment to the functioning of the frontal portion, memory to the posterior portion, and imagination to the intermediate portion of the brain. In modern times, Gall has attempted to make a one-to-one correlation between some thirty-five or forty mental faculties and a corresponding number of specific brain areas. Remnants of this theory still prevail in theories of brain localization (Boring, **2**, Chap. 3).

An off-shoot of the problem of location of mind is that concerning the participation of the physical body and particularly the nature and *locus* of the physical changes taking place in the learning process. Theories have been formulated which assume that neural patterns are made up of sharply channeled pathways composed of reflex arcs including synapses. Learning is supposed to result from the canalization of impulses through the elaboration and modification of these reflex arcs. This modification takes place at the synaptic junction and, probably, through the influence of Sherrington, it is assumed to be in the form of a reduced resistance to the propagation of the impulse across the synapse. The reflex arc theories, in a word, assume relatively neat, atomistic and mutually insulated stimulus-response-connections. Support of them is found among the writings

[1] The writer gratefully acknowledges his indebtedness to the Committee on Faculty Research of the University of Oklahoma for a grant to defray the expense incurred in making the material on chronaxie available for this discussion.

of Pavlov, Watson, Thorndike, and others (Tolman, 60, pp. 371–388).

Other theories of learning, which Tolman has called the field theories, are based on the assumption that learning consists in some sort of a reorganization relative to an entire stimulus-field. When the animal learns it does not merely make new responses to old stimuli. It makes these new responses because its whole perceptual and other cognitive adjustments relative to the entire stimulus-field have been fundamentally "remade, reorganized, regestalted". Proponents of such theories are Tolman, Koffka, Köhler, Wheeler (Tolman, 60, p. 389 ff.), and Hoisington (19).

These functional theories possibly are gaining an ascendancy over the atomistic ones mentioned above. However, their position would be strengthened if further physiological data to supplement the psychological facts upon which they are based could be secured and brought together. A recent experimental movement in physiology holds some promise of supplying this need. It concerns the measurement of excitability of living tissue in terms of a time factor rather than an intensity factor. The term applied to this unit of measurement by Louis Lapicque, the French physiologist who is leading the movement, is *chronaxie*. It is the purpose of this paper to discuss the results obtained in the experimental study of chronaxie and to indicate the psychological significance of some of the findings. This is done with the hope that a few psychologists will collaborate with some of the physiologists in formulating a program of research which shall result in the mutual advancement of both psychology and physiology. However, space will not permit a complete summary or even a citation of all the 1,000 to 1,200 studies on the subject. (Incidentally, it is an indication of the strength and vigor of the movement to note that a very large portion of these studies has been made since 1925.)

Historical

Excitability of a tissue is the property it has of responding, by a modification of its shape, location, state or constituency, to a change in its surrounding medium called the stimulus. The nature of excitability of most tissue is not directly measurable. But the stimulus required to excite is readily subjected to measurement. For decades, due to the influence of the teachings of Du Bois-Reymond, excitability of the nerve was measured only in terms of intensity of the stimulus (Lapicque, 26). No consideration was given to the nature of the current or of its duration. This was due

to the fact that the standard physiological 'rheoscope', the sciatic-gastrocnemius preparation of the frog, rather than some other preparation, was used and a constant current was employed as the exciting agent. Du Bois-Reymond observed that this agent was effective only at the make or break of the circuit and concluded that the excitant was not the current itself but a change in intensity of the current. It is known that striped and unstriped muscles vary greatly as to the time required to excite them. The 'making' slope of the constant current must be very steep for striated muscles but it may be much slower for smooth muscles. Du Bois-Reymond found that the threshold stimulus for the sciatic-gastrocnemius preparation did not vary with durations ranging from 1 to .005 second. He concluded, therefore, that intensity but not duration was a factor in excitation. If he had used plain muscle, such as muscles of Anadonta, rabbit's ureter, muscles of Cyclops, etc., as used by other physiologists a few years later, he would have discovered that the time factor was very important in excitation.

However, so great was the prestige of Du Bois-Reymond that for more than sixty years this fundamental error was taught. Although the time factor was employed by contemporaneous investigators, as Brücke, Englemann, and Fick, in experiments on excitability, yet it was not until the latter part of the nineteenth century and the beginning of the twentieth century that duration was used extensively in physiological research. Lapicque (**26**, p. *227* ff.) claims priority in the use of an unnamed duration unit (1903) which he later (1909) called chronaxie, although Lucas used a similar unit in 1907.

The justification for the use of the time factor instead of the intensity factor in studying excitability is many fold. On the experimental side it does away with the extreme uncertainty of threshold intensity. The threshold varies with many factors, such as variability of resistance of the organism from time to time and from animal to animal, making it impossible to make comparisons between species; the position, shape, size and grade of imbibition of electrodes; and other factors. However, with chronaxie the rheobase may vary under differing conditions but the chronaxie will remain the same. For example, Salmonson (cited by Fredericq, **18**, p. 515) gives the following chronaxie readings for a given tissue under three types of stimulation:

Stimulus	Rheobase in Milliamp.	Chronaxie in Secs.
Condenser discharge	4.4	0.00008
Induction shock	6.1	0.00008
Constant current	2.3	0.00008

When it comes to interpreting the results, the duration or chronaxic method has almost unlimited advantages over the intensity method. It reveals differences between fast and slow muscles and striped and unstriped muscles that were not known before. The influence of temperature, fatigue, stretching, and drugs comes in for a fair share of enlightenment. Furthermore, functional relationships of whole functional systems are presented in a new light in terms of chronaxie which provides extensive possibilities in formulating a principle of integration of behavior. One point that has been brought out in Lapicque's work is an apparent universality in the relationship between intensity and duration as shown by intensity-duration curves. He (26, p. 220 ff.) holds that strength-duration curves of all tissues will coincide if they are properly scaled. Closeness of fit in these cases is, as Lapicque points out, quite as good as would be obtained from two specimens of the same species.

Chronaxie is defined in this way. Using a constant current, it is first necessary to determine the intensity just sufficient to excite the tissue in question in an indefinite time. Then this threshold intensity, *rheobase,* as Lapicque calls it, is doubled. Now, the time required to excite with the use of this strength of stimulus is called *chronaxie.* By measuring sensitivity in this way one uses what one would call two parameters in mathematics—rheobase, or the threshold of intensity for all durations of current beyond a certain minimum, and chronaxie, or the threshold of duration of current for an intensity double that of the rheobase (Lapicque, 26, p. 230 ff.).

The multiple of the rheobase to be taken for what we may call the ' working stimulus ' is somewhat arbitrary. However, it should be taken at a point on the intensity scale where the intensity-duration curve is not too flat, rendering indeterminate the duration. Likewise it should be taken at a point where this curve is not too steep, rendering the determination of intensity difficult. An intensity of twice the rheobase avoids both of these difficulties.

Method

Chronaxie can be measured experimentally either by the constant current method or the condenser discharge method.

Constant Current Method. With the constant current method the following equipment is needed: an electric source, a potentiometer for modifying the voltage, switch controls, a rheotome for varying the duration, and a set of resistances.

Various rheotomes have been used, as the pendulum of Helmholtz and of Lucas, the ballistic rheotome of Weiss, and Lapicque's

Chronaximeter, all described by Lapicque (**26**, Chap. 13). In addition, there is the interrupter of Boruttau, the chronaximeter of Brillouin, the time key of Erve, and the chronaximeter of Noyons, each of which has been used for measuring the time interval. The duration is read off directly in thousandths of a second.

The Condenser Discharge Method. With this method a very high capacity, a capacity which is practically infinite, is needed. It is known that the duration of discharge from a condenser is proportional to the capacity used so long as the resistance of the circuit does not vary. The resistance of the subject is likely to vary somewhat during the experiment but this variation is made negligible by introducing into the circuit a very high resistance, say, from 10,000 to 20,000 ohms. In addition to the condensers there is required a potentiometer for measuring the loading potential, two sets of resistances and a doubling switch. Chronaxie is read off by this method in microfarads. But this value is easily translated into thousandths of a second by substituting in the following formula: chronaxie=R C K, where R is the resistance, C is the capacity and K is equal to .375. That is, it has been found both experimentally by Lapicque (**26**, p. 323) and mathematically by others, that the ratio of chronaxie to the product of resistance times capacity is 3 to 8.

The procedure for finding the chronaxie of a given tissue, say, by the condenser method, is somewhat as follows: The condenser dials are set at a high capacity. The potentiometer is set at a voltage judged to be slightly above the estimated rheobase of the tissue in question and the tissue is stimulated. The voltage then is decreased until the intensity of current is just sufficient to produce a response. The reading at this point is the rheobase. Next, the rheobasic current is doubled at its source. Then the capacity of the condenser is reduced until the amount is just adequate to give a perceptible response in this tissue. The reading now gives the chronaxie in microfarads, which can be reduced to thousandths of a second, if desired, by use of the formula mentioned above. (For more complete details of apparatus and method see Lapicque, **26**, Chaps. 6, 7, 13, 14, 15.)

The relative merits of the two methods are noted by Lapicque (**26**, p. 324 ff.). He prefers the chronaximeter with the constant current since it is more accurate than the condenser method. But the latter has the greater range of accuracy since the time in this way can be measured at least to .00001 second while the chronaximeter, with the latest perfection of this feature noted (1926), can register not less than .0025 second.

Factors Affecting Chronaxie

Drugs. Many factors are known to modify the chronaxie of excitable tissues. The one most extensively worked out is drugs. Probably, the influence of a total of 100 drugs has been subjected to experimental control, the results of these studies being so extensive that space here will permit only the briefest summary of them.

Some drugs are specific for slow muscles and others for rapid muscles. Still others modify only the chronaxie of nerves. As will be shown later in the discussion of curarization, the peculiar effects of curarizing drugs are readily explained in terms of chronaxie.

Imbibition. Excitation, according to the Nernst theory, is caused by changes in the distribution of ions along the limits of distinct colloidal phases or the surfaces of semipermeable membranes. If chronaxie is short, the division of ions must be rapid. The permeability of a tissue can be increased by increasing the amount of imbibition. Therefore, theoretically, an agent which increases the degree of imbibition in a tissue should also lessen its chronaxie. Contrarily, chronaxie should be lengthened if the agent reduces the imbibition. And this assumption has been amply justified experimentally (Fredericq, 18).

Glandular Secretion. Adrenalin increases the chronaxie of the frog's intestine, the heart, the blood vessels and muscles in saturnism. It decreases that of the frog's interdigital membrane, the gastrocnemius muscle and the claw muscle of the crab. In the nerve-muscle preparation of frog there is a distinct lengthening of chronaxie when synthetic thyroxin is applied. An extract of hormonal character has been prepared from the thyroid gland of previously eserined animals, which, when injected into dogs, lowers the chronaxie of the psychomotor centers of the sigmoid gyrus. The preparation seems to act directly on the excitability of the cerebrum rather than through metabolism, since the same results have not been obtained with thyroxin. Extracts from the posterior lobe of the hypophysis and from the ovaries increase cutaneous chronaxies.

External Physical Conditions. As will be shown under localization, electricity, light and temperature, applied at the periphery as well as directly, modify the chronaxie of cortical points controlling motor organs. Temperature also modifies sensory and motor chronaxies when applied to the organism as a whole. For example, motor chronaxies in frogs are ten times as long during the winter as at the close of the summer season.

Physiological Conditions. Ligation, compression, and hemorrhage modify the chronaxie of neuromuscular organs, increasing it in some

and decreasing it in others. In the sartorius muscle of the human, the chronaxie is greater just after complete rest (sleep) than under normal conditions. Nerve-muscle chronaxie begins to increase from the time drowsiness sets in and continues to increase until it reaches its maximum at deep sleep. Normal chronaxie is reached quickly after awakening.

Physical Activity, Work and Fatigue. The chronaxie of extensors of the fingers is increased with work electrically aroused, the change usually occurring after cessation of muscular activity. This delay in change of chronaxie seems to be related to the vascular state of the muscle and to chemical conditions during activity and after recuperation. After lifting a weight there is an increase in the chronaxie of the muscle involved, the increase being proportional to the amount lifted and less affected by duration of the work. Muscular chronaxie increases with onset of work, but the augmentation diminishes with training though the absolute amount done may increase. When other muscles are fatigued, the chronaxie of the biceps is lowered, due presumably to the flooding of the latter with lactic acid. Augmentation of chronaxie resulting from exercising a muscle tends to disappear after massaging the muscle.

Mechanical distension and stretching of muscles modify their chronaxie but the results are conflicting. Posture of a member in the intact organism modifies the chronaxie of the motor nerves and centers concerned. This phenomenon seems to be a phase of the chronaxie of subordination and of constitution, to be discussed later in the paper. Lapicque (**32**) believes that these chronaxies are regulated by a proprioceptive reflex. He found that in the intact muscle there was a decrease in chronaxie ranging from 25 to 60 per cent in changing the muscle from an extended to a flexed position while no decrease resulted from change of posture when the nerve was sectioned.

Speed of Conduction and Size of Tissue. Chronaxie is inversely proportional to the speed of conduction. It is also known that the more rapidly the nerve impulse is propagated the more rapidly the impulse is developed at the point of excitation. Roughly and tentatively stated (Lapicque, **26**, p. 356), the nerve impulse travels 1 cm. per chronaxie. The chronaxie of a nerve is inversely proportional to the size of the nerve. Nerves of equal diameter have equal chronaxie. A single electric shock will send out impulses of varying speeds because the nerve has fibers of different diameters. The phrenic, whose fibers are more uniform, however, does not present

this phenomenon. This makes it possible to use chronaxic methods in identifying and determining the ramification of nerves.

Individual Differences. Chronaxies vary with species, individual, sex, and age. As to species (rat, cat, guinea-pig, dog, and pigeon) the size of the optimal chronaxie of a cortical motor point appears to be correlated with the degree of anatomical and functional importance of the hemispheres. In the higher species the chronaxies of these points are smaller than in the lower animals. The data on sex are limited and conflicting. As to age, the motor chronaxie of the infant is about ten times that of the adult. There are lacking also in the child characteristic neuromuscular isochronisms (equal chronaxies) characteristic of the adult. These, however, begin to appear about the fifteenth month or when the child begins to walk. The higher chronaxies of childhood gradually decrease until near adolescence when they approximate those of the adult.

Isochronism

According to Lapicque the principle underlying the interrelationship of two tissues or two functional systems is that the one must be isochronous with the other. This holds for the central nervous system and skeletal muscle system, but not for the autonomic and visceral systems. That is, for an impulse to pass from Neurone A to Neurone B, the former must be isochronous with the latter (Lapicque, **26**, Chap. 12). The limits of variation within which isochronism is supposed to exist have not been determined for two nerves but it has been determined for nerve and muscle. Bourguignon (**17**) has shown that the chronaxic ratio between muscle and nerve may vary between 1 : 1 and 1 : 3. When the ratio exceeds 1 : 3, the functional relationship between them is lost and a state of heterochronism is said to exist. However, as the intensity of the stimulus increases, more and more segments may be brought into functional relationship.

Chronaxie of Some Functional Systems

For purposes of discussion, the data on chronaxie will be discussed under four heads, namely, sensory systems, nervous systems, motor systems, and interrelationship of these systems. These divisions are purely arbitrary and are not mutually exclusive.

Sensory Systems

Cutaneous. Bourguignon has done more work than any one else on the chronaxie of sense organs and the reader is, therefore, referred to his studies for more details (**4**, **5**, **10**, **11**, **14**). In the realm of skin sensations, chronaxies of points producing such qualities as

pressure, sharp prick, shock, tingling, pain, and heat have been determined. However, no value has been found for cold points. The law of isochronism holds for some of the receptors at these cutaneous spots, in that their chronaxies are the same as those of the sensory nerves leading off from them and also those of the muscles subjacent to them. For example, the skin of the anterior portion of the arm has points of shock whose chronaxies, which range from .06σ to .14σ, are the same as those of the muscles below them. The shock points on the posterior portion of the arm have chronaxies of .40σ to .70σ which are equal to those of the posterior muscles. The chronaxies for points of itching on the same anterior portion of the arm are .30σ to .70σ and those for points of heat are .60σ to 1.40σ. The chronaxies of corresponding points on the posterior side of the arm are 2.0σ to 3.5σ and 4.0σ to 7.0σ. From these results Bourguignon (17) has established the law of regional sensori-motor isochronism. He also assumes that the largest chronaxies (heat) are those of the free endings in the epidermis, the medium chronaxies (itching) are those of the Meissner corpuscles in the skin, and the smaller chronaxies (shock) are those of Pacinian corpuscles of the hypodermis. (It is to be noted that these assignments of punctuate sensitivity do not correspond to the traditional designations.)

Visual. With electrical stimulation of the eye, the chronaxies of the phosphanes produced range between 1.1σ and 1.9σ at the periphery and 2.1σ to 2.8σ at the center of the retina. It is probable that the shorter chronaxies correspond to the retinal rods and the longer ones to the retinal cones. In the optic tract there are two chronaxies, the larger corresponding to excitation of the fovea, the smaller to excitation of the peripheral portions of the retina.

Auditory. When the ear is stimulated by tuning forks, the chronaxie of auditory excitation varies inversely with vibratory frequency. For example, at 1,000 d.v. the chronaxie is 34σ but at 100 d.v. it is 232σ. Furthermore, since the excitation must be summated, the limits of summation are also inversely proportional to vibratory frequency. For 1,000 d.v. the limit of summation is 125σ and for 100 d.v. it is 674σ. Due to the fact that different vibration frequencies are associated with different chronaxies, one is led to admit specificity in auditory reception. There must be an intimate relation between excitatory frequency and the temporal properties of the neurone aroused. In the light of these results Kucharski (24) is of the opinion that the chronaxic properties of the auditory mechanism may constitute the point of departure for a theory of audition.

Gustatory. Differential chronaxies of the tongue are in agreement with the different innervations. That is, the chronaxie at the apex is 1.4σ to 1.8σ and that of the lingual V is 0.3σ to 0.5σ. No measurement of the chronaxies of these gustatory tracts has been worked out to the knowledge of the writer.

Vestibular. Vestibular chronaxies lie between 12σ and 22σ, there being distinct chronaxic values for each of the three canals. The horizontal canal has the smallest, and the sagittal vertical canal the largest chronaxie. The relationship of the smallest to the middle and of the middle to the largest is as 1 : 2. In the vestibular nerve, Bourguignon (11) finds distinct chronaxies for different degrees of emotivity. Those individuals whose vestibular chronaxies are between 12σ and 16σ are very emotional, while those with chronaxies above 17 are very calm. In air pilots the vestibular chronaxie may decrease as practice in piloting progresses.

In surveying the sensory chronaxies one is struck with the relatively high values obtained in some of the modalities. The vestibular values range from 12σ to 22σ, the auditory from 34σ to 232σ (for vibration frequencies used), and some of the cutaneous run as high as 7σ. The fact that the auditory excitation must be summated tends to place the auditory mechanism in the class with what Lapicque called 'iterative nerves'. The high chronaxies may be due to the peculiar nature of the stimulus, namely, its vibratory effect. One would like to know what the chronaxie is when the stimulus is an abrupt sound with no particular tonal quality.

The excessive vestibular chronaxies may be due to the close association of the vestibular nerve with the autonomic system whose chronaxies are generally high. In the cutaneous end-organs there is isochronism between the shock spots and the motor chronaxies of the same regions, but for the tingling and the heat spots the chronaxies are considerably higher than those of the motor organs. Here again, as Bourguignon (17) points out, the autonomic system enters in to complicate the functional relationship between the sensory nerves and the muscles of the corresponding regions. However, he does tend to find isochronism between sensory nerves of the skin and their sensory endings, just as he finds isochronism between muscles and motor nerves.

Motor Systems

Skeletal muscles have short chronaxies and visceral muscles have long chronaxies. The former are usually isochronous with the motor nerves but this need not be true of the latter. In fact the visceral

muscles are usually heterochronous with the nerves which innervate them. In order to stimulate a visceral organ it is generally necessary to summate the stimulus, that is, repeat it many times. For example, in the vasoconstrictors of the frog and the dog, the chronaxie of the nerve is about 2σ but that of the terminal organ is approximately 100σ. These two types of muscle also react differently to drugs. Skeletal muscles are curarized by some drugs while visceral muscles are curarized by other drugs.

One of the notable characteristics of the functional arrangements of skeletal muscles is their antagonistic relationship. Studies of muscular chronaxie reveal that the chronaxies can serve as a basis for differentiating the muscles involved into flexor or extensor, anterior or posterior, and proximal or distal muscles. Bourguignon (15) finds that the chronaxie of the extensors is longer than that of the flexors and that the ratio of the former to the latter is always between 1 : 2 and 1 : 3 for all regions of the body and for all species. Another interesting point is the fact that all muscles which contribute jointly to the same function, that is, the synergistic muscles, have the same chronaxie. For example, consider the following sets of opposed muscles:—*Arm:* flexors and internal head of triceps brachii, $.08\sigma$ to $.16\sigma$; their antagonists, $.16\sigma$ to $.32\sigma$; *Forearm:* flexors and pronators, $.20\sigma$ to $.36\sigma$; extensors and supinators, $.44\sigma$ to $.72\sigma$; *Thigh:* muscles for forward directed movements of thigh and leg, $.10\sigma$ to $.16\sigma$; those for backward directed movements, $.40\sigma$ to $.70\sigma$; *Leg and foot:* muscles for forward directed movements, $.24\sigma$ to $.36\sigma$; those for backward directed movements, $.40\sigma$ to $.70\sigma$; *Face:* depressors of features, $.24\sigma$ to $.36\sigma$; elevators of the features, $.48\sigma$ to $.72\sigma$.

In the proximal group Bourguignon places the muscles of the neck, trunk, shoulder, upper arms, hips, and thighs. In the distal group he puts the muscles of the head, face, forearms, hands, legs, and feet. The chronaxies in the proximal group are $.06\sigma$ to $.14\sigma$ for posterior muscles. In the distal groups the anterior muscles have chronaxies of $.16\sigma$ to $.34\sigma$ and the posterior muscles have chronaxies of $.40\sigma$ to $.70\sigma$. Thus it may be seen that chronaxies of skeletal muscles may be divided into three groups, namely, those with small chronaxies, $.06\sigma$ to $.14\sigma$; medium chronaxies, $.16\sigma$ to $.34\sigma$; and great chronaxies, $.40\sigma$ to $.70\sigma$.

The concept antagonistic muscle needs to be modified somewhat. In most of the posterior muscles there are two sets of fibers with two distinct chronaxies and two motor points. The chronaxie at one

motor point is the same as the chronaxie of the anterior muscle. That at the other motor point is two to three times that of the anterior muscle. Now, it is only those fibers which have the larger chronaxies that may be called antagonistic to the anterior muscles, for those that are isochronous with the anterior muscles are really synergistic. It is their function to serve as a check against the contraction of the anterior group. If this were not the case, the latter would be put into action so quickly there could never be deliberate or precisely synchronized movements. It should also be noted that the motor nerves for the posterior muscles have two chronaxies equal to those of the two motor points. In fact it is the opinion of Bourguignon that this 'check' function is the primary function of the posterior muscles and that extension is only a secondary function.

Disturbance of this temporal arrangement of opposed muscles and of the nerve-muscle relationship is the basis for many motor disorders due to pharmacological and traumatic conditions, as will be shown in a later section on pathology.

Nervous Systems

A vast amount of work has been done on excitability of the autonomic nervous system in terms of chronaxie, but the results are so widely spread that it is hardly worth while to attempt to bring them together in the limited space here available. Therefore, only the central system will be considered, except where the autonomic is concerned incidentally.

The bulk of chronaxic material on the cerebral cortex has been worked out by Rizzolo, the references to which are too numerous to cite here. He has found that the chronaxie of the cortex is the same as that of the subjacent white matter. In fact, Chauchard and Chauchard (*cf.* Bourguignon, 9) have found that there is isochronism all along the motor tract from the cortex to the peripheral muscle, observations being made at the level of the cortex, the corona radiata, the internal capsule, the cerebral peduncle, the medulla, and at lower levels along the motor tract.

Another point of interest concerns the reciprocal action of the two hemispheres as indicated by chronaxic measurements. For example, when a thermal, electrical, or chemical excitant is applied to a zone of the cerebral cortex the chronaxie of the corresponding zone in the other hemisphere is also modified. Since the results are the same after sectioning the corpus callosum as before, the reciprocal influence cannot be mediated by this commissure. This reciprocity is also observed when an excitant is applied to an external member.

Thus if the paw of a dog is plunged into cold water, not only the chronaxie of the motor zone corresponding to this member will be modified, but that of the symmetrical zone will also be modified, although to a less degree.

When a lateral lobe of the cerebellum of the dog is stimulated electrically it causes an increase in the excitability of both sides of the cerebral cortex, but the increase is always more marked on the side of the cortex contralateral to the cerebellar lobe stimulated. This indicates that each lateral lobe is connected with only one side of the cerebral cortex, namely, the opposite side.

Many factors, such as drugs, ligation of carotids, hemorrhage, temperature, and trauma, modify cortical chronaxies, some lengthening, others shortening the values. More will be said about this point under chronaxie of integrated functional systems.

Chronaxies of the spinal cord have also been studied by Rizzolo. He found the same chronaxies for the cervical, dorsal, and caudal regions in the cord of the *Scillyorphinus canicula*. After complete transection in each of these regions there was no variation in chronaxic values.

More will be said in the next section, interrelation of functional systems, about chronaxie in the central nervous system.

Chronaxic Interrelationship of Functional Systems

Curarization. Some drugs have a curarizing effect upon a nerve-muscle complex. That is, after application of the drug the muscle is inexcitable by indirect excitation through the nerve (but can still be stimulated by direct stimulation), although excitability of the nerve is unaffected. The difficulty is essentially one of transmission of the impulse from nerve to muscle. All physiologists, it seems, are agreed as to this fact, but they differ as to the assigned cause. The traditional viewpoint is that between the nerve and the muscle there is interposed a special organ, the end-plate. Curare and other curarizing drugs affect the end-plate. The end-plate becomes impermeable to the nerve impulse.

But according to Lapicque (26, Chap. 12), the end-plate is merely a laboratory abstraction; it is, in reality, a myth. What has really happened in curarization is that the drug has lengthened the chronaxie of the muscle so that a state of isochronism between them no longer exists. If the theory is correct, there should be four conditions under which curarization could take place. These are lengthened muscle chronaxie with unchanged nerve chronaxie (*e.g.*, curare, spartein,

fatigue); shortened muscle chronaxie with nerve chronaxie unchanged (*e.g.*, veratrin); lengthened nerve chronaxie with unchanged muscle chronaxie (no drug known to have such effect); and shortened nerve chronaxie with muscle chronaxie unchanged (*e.g.*, strychnine). All of these conditions of curarization, except that of lengthening the nerve chronaxie, have been determined experimentally.

When a muscle has been curarized by fatigue, normal isochronism can be restored in any one of the following ways: (1) by allowing time for the organism to recuperate from fatigue, that is, by allowing the nerve and muscle to restore their functional equilibrium; (2) by exciting the sympathetic roots of the fatigued muscle; and (3) by injecting adrenalin into the muscle. All of these agencies decrease the augmented chronaxie of the muscle.

A very neat and at the same time crucial experiment has been worked out in this way by Lapicque to verify his theory. When a nerve-muscle complex has been curarized by veratrin, which shortens the chronaxie of muscle, it can be restored to a functional state by application of strychnine, which shortens the nerve chronaxie. According to Lapicque, the curarization in the first place was due to a state of heterochronism caused by shortening the muscle chronaxie by the veratrin. Under the second condition the chronaxie of the nerve was shortened to a corresponding degree and hence neuromuscular isochronism was restored.

Lapicque's theory of curarization is opposed by the findings of Lucas (**41–44**) and Rushton (**52–59**). Lucas found in the toad's sartorius muscle three excitable substances. One substance, alpha, had an excitation which was much longer than that of the nerve innervating the sartorius. Another substance, beta, had an excitation time much shorter than the motor nerve. A third substance, gamma, had an excitation equal to that of the muscle. Lapicque (**26**, p. 249; **27**, **28**, **29**, **30**, **31**, **34**, 35, **36**, **37**) holds that the alpha and beta values are not comparable to his chronaxies for three reasons. First, Lucas used fluid electrodes which may have distorted the lines of current flow in their neighborhood. Secondly, the tissue may not have come into equilibrium with the surrounding fluid, giving differential stimulation of superficial and deeper fibers. Thirdly, experimental errors in getting data may have crept into his technique, which would give the discontinuities in the intensity-duration curves on which his conclusions are drawn.

During the past five or six years Rushton and Lapicque have waged a heated battle concerning the validity of the data obtained by

Lapicque and Lucas. Rushton recast the experiments by Lucas with greatly improved technique and verified the presence of the alpha and the gamma substances got by Lucas. However, he was unable to obtain the curve indicating the presence of the beta substance. Lapicque counters with the charge that the chronaxies obtained by Rushton are pseudochronaxies, since they were obtained under conditions at variance with those according to which chronaxie was originally defined. His quarrel concerns particularly the influence of variation in size of the electrode, which, it is known, will influence the chronaxic value. Whereas Lapicque used very small electrodes of a known area, Rushton used greatly diffused electrodes in most instances because he used the solution in which the muscle was immersed as the active electrode.

The methods used are so different in many respects that it seems impossible for these experimenters ever to harmonize their points of view. It may be that the presence of two chronaxies for the myoneural complex is inimical to Lapicque's theory of curarization. However, it seems that, with certain modifications of Lapicque's concept, the Rushton data could be incorporated in it. In fact the theory would then harmonize with certain other data on muscular physiology. In the first place there are the two kinds of contraction, tonic and phasic. It would seem that the tonicity of muscles can be maintained continuously although there may be intermittent phasic contractions. It has been claimed that the fibrillae are phasic and the sarcoplasm is tonic in function, and also that muscle fibers are of two sorts, the white, which are phasic, and the red, which are tonic.

As has been pointed out before, some of the skeletal muscles, the extensors, especially, have two peripheral motor points, the one with a chronaxie equal to that of the flexors and the other with a chronaxie double that of the flexors. Furthermore, excitation at one of these points causes the whole muscle to contract while at the other it causes only partial contraction. It has been shown (Marinesco *et al.*, 45) that in patients afflicted with facial paralysis the constitutional chronaxies of the facial muscles are very much longer after anaesthetizing the nerve and releasing the contraction. It is assumed by the authors that there are two groups of muscle fibers with distinct irritabilities, those with shorter chronaxies (0.09σ to 0.78σ), functioning when the muscle has normal union with the nerve, and those with longer chronaxies (ranging up to 2.30σ), when the muscle is anaesthetized. Only small chronaxies appear in the unanaesthetized nerve because the rapid fibers respond to every stimulus and mask

the appearance of reaction by the slow fibers. It has also been shown that the claw muscle of the crustacean makes two distinct contractions.

In the study of repercussion in the rabbit, Bourguignon (13) finds that motor chronaxies vary not only with changes that take place throughout the nervous system but through modifications of internal conditions such as vascular and glandular changes. He concludes, therefore, that there must be two excitable tissues in the nerve-muscle complex, the intramuscular nerve fibers and the extramuscular fibers.

Constitutional and Subordinate Chronaxie. The Lapicques (32, 33, 38, 39, 40) have found that the chronaxie of a muscle or nerve is not only determined by its own substance and structure, but by the functioning of the other nerves. This fact was noted when it was discovered that the sciatic nerve in the decerebrate or injured frog had a variable chronaxie, generally smaller than the value found in the severed leg. Cutting off the nerve from the spinal cord, transecting the bulb, or removing the control of the higher centers in any other way, restored the chronaxie to a constant value. The chronaxie of the tissue which is dependent upon the influence of the centers is called subordinate chronaxie and that of the tissue in its own right, that is, not subject to central control, is called constitutional chronaxie. The former is governed reflexively, the principal factor being the tension of the muscle concerned. In the case of the gastrocnemius, the chronaxie of the nerve is greater when the foot is flexed, thus stretching the muscle. Severing the nerve eliminates any influence of posturing upon chronaxie. It has also been shown that lesion of the sensory nerve leading from the region of the muscle concerned modifies the chronaxie of subordination of the neuromuscular complex.

Another phenomenon closely related to subordination is repercussion, a term used by Bourguignon (3, 13, 16) to designate the influence of injury or other pathological conditions of a nerve upon the chronaxie of other nerves. The lesion of a neurone can react upon the chronaxie of the neurones which are functionally associated with it. This effect may take place at some remote point, through the influence of the intermediate centers. For example, by compression of circulation in the left upper arm for a period of 25 minutes, there is a change in chronaxie and rheobase at the motor points of muscles in the nose and face of the opposite side of the body. The chronaxie begins to decrease within six to twelve minutes and reaches eventually about half the normal chronaxie, which it maintains until decompression. The minimal value is attained when paralysis is

complete in the compressed member. Normal nerves and muscles of the same or opposite side, provided their chronaxies are equal to those of the nerve in question, are likewise affected with the injuring of a nerve. For example, after sectioning of the ulnar nerve of one side, the chronaxies of the median of the same side and of the ulnar and median of the opposite side are modified. However, nerves with widely different chronaxies are unaffected. In some cases repercussion can go to the extreme of producing a typical reaction of degeneration, of which sympathetic ophthalmia is an example.

Cortical Localization and Cortical Motor Points. An extensive study of the stimulable areas of the cortex has been made by Rizzolo with a view to determine their chronaxic values. He finds that the chronaxie of an area whose stimulation arouses a response in some peripheral muscle is variable but that in each functional area there is one point whose chronaxie is lower than that of any other point. This he calls the optimal motor point and he uses this point in most of his studies of cortical excitability.

The chronaxie of a given optimal motor point varies with many conditions, such as posture and temperature of the corresponding peripheral member, heat, cold, and drugs applied directly to the cortex, and the species in question. Destruction of the tissues of the optimal motor point seems to have no effect upon the chronaxie of the non-optimal points. One is made to wonder if this is in violation of the law of repercussion. If not, there must be rather sharp selectivity in its operation. Heating the paw of the dog by immersing it in water at 55° decreases the chronaxie of the optimal motor point for this member from 30 to 58 per cent. If, however, the immersion is prolonged to seven minutes the chronaxie is increased to 87 per cent above the normal. Cooling, on the other hand, has the opposite effect. Electric stimulation of the skin of the paw gives first a decrease in the optimal chronaxie; later stimulation may result either in further decrease or in an increase of the chronaxie. Furthermore, there is a change in the chronaxie of the corresponding optimal motor points of the opposite side, though the change is less marked. The application of nicotine to the optimal motor point for winking the eye of the dog at first decreases the chronaxie but after the third application there is always an increase, which may go to 100 per cent above the normal.

Arrestment of heart action caused by peripheral stimulation of the vagus results in a distinct decrease in the chronaxies of optimal motor points in the cortex. After resumption of cardiac activity there

is an increase which may exceed the normal, although the increase may not always be immediate. Applications of strophantin, theine, and caffeine first decrease and then, with subsequent applications, increase the optimal chronaxie.

When both eyes are kept in practical darkness for a time the chronaxie of both points for winking is increased. Total darkness for an hour or two brings about a diminution of the chronaxie of the motor point. When the stimulation of one ear of the dog has been partially eliminated for 30 to 60 minutes, there is a decrease in the excitability of the part of the cortex controlling the movement of the ear. A stimulus of 3,096 d.v. from 5 to 20 minutes increases the chronaxie of other regions on both sides of the cortex.

Rizzolo (**51**) has pointed out the value of the use of chronaxic method in studying the localization problem. In the ablation technique there is much destruction of tissue, which, it has been shown, modifies the excitability of the tissue remaining intact. The question arises as to when, if ever, does the intact tissue regain its normal excitability. This can be determined by chronaximetric methods. Rizzolo repeated some of the localization studies by Lashley, particularly the brightness discrimination problem. As a result, he takes Lashley and other American psychologists, who have worked on this problem, seriously to task because they have not only failed to give the tissue sufficient time to regain its equilibrium in excitability but have not seemed to be concerned about the question. Despite the fact that the point is well taken, one is struck, nevertheless, by the close agreement between his results and those of Lashley. Apparently those of the latter were not vitiated to any extent by this haste or oversight.

As has already been indicated, there is isochronism between the optimal motor point of a given cortical zone and the subjacent white matter. This need not necessarily hold true for non-optimal points in this area, however.

Pathology

In the realm of pathology much work has been done in terms of chronaxie by Bourguignon (**8, 9, 10, 12, 13, 16, 17**) and Marinesco (**45–49**). Bourguignon's discovery that the chronaxie of peripheral muscles and nerves, and even of brain tracts, can be measured from the surface without exposing the tissues by operation has opened up a very important method of diagnosing some organic and some mental diseases. This has made it possible to determine the chronaxie of practically every muscle and many of the receptors in

normal man, with which can be compared the chronaxie of corresponding tissues in pathological cases. With these results and those of Lapicque, several chronaxic principles governing normal neuromuscular functioning could be formulated. These will be stated in the section on interpretation.

On the basis of these principles a number of chronaxic syndromes have been described. Bourguignon (12) has grouped these syndromes as follows: (1) peripheral, which are subdivided into myopathic and Wallerian; (2) reflex; and (3) central, with subdivisions of pyramidal, extra-pyramidal, cerebellar, and medullary. There are syndromes which possibly could be formulated from other viewpoints. Without attempting definitely to classify them, several abnormal chronaxic patterns will be presented to illustrate the value of chronaxie in electrodiagnosis in pathology.

In subjects afflicted with hemeralopia through pigmentary retinitis there may be heterochronism between multipolar and bipolar neurones of the rods during the day and a disappearance of this heterochronism during the night. No heterochronism has been observed in cone connections, however.

Stimulation of the pyramidal system of normal man gives the same chronaxie as does peripheral stimulation of the neuromuscular system. In cases of head injury, however, there is appreciable heterochronism between the two. There is greater heterochronism between the pyramidal tract than between the motor nerve and its muscle. In fact, the latter two may retain their normal isochronism even in hemiplegia, although the chronaxie of both is invariably raised.

In children afflicted with rickets, the chronaxie of muscles of the limbs is augmented from 2 to 9 times its normal value. Pellagra modifies especially the chronaxie of the limbs, bringing the posterior and anterior muscles together. It also tends to increase their tonicity. Certain investigators hold that in this disease there is a lesion in the mesencephalon, where the centers *(locus niger* and *globulus pallidus)* are probably true sympathetic centers for muscles. There anything affecting them would bring with it, due to the absence of inhibitions, reflex muscular tonicity or sarcoplasmic rigidity.

In patients afflicted with latent tetany resulting from thyroidectomy, it has been observed that there is rigidity in the hands. In this case there is an increase in the chronaxie of the cubital nerve and heterochronism between the nerve and the muscular motor points. If there is a dominance of rigidity in one hand or the other, the

increase in nerve chronaxie and the degree of neuromuscular heterochronism are greater on the side of the greater rigidity. Voluntary hyperpnoea in these patients hastens the seizure and increases rapidly the chronaxie of the muscles seized. This increase, likewise, is greater on the side most severely tetanized. In tetany poisoning there is a diminution of neuromuscular chronaxie, the larger chronaxies being reduced more than the smaller ones, which tends to equalize the chronaxies of the opposed muscles. The more severe the seizure the closer do the two sets of chronaxies tend to approximate each other.

Three different variations in anterior-posterior muscle chronaxies have been observed in Parkinsonism in post-encephalitis: (1) equalization of chronaxie at the motor point; (2) change in ratio of the two chronaxies, resulting from either a decrease of the flexor chronaxie and an increase in extensor chronaxie, or a decrease in extensor chronaxie and an increase in the flexor chronaxie; and (3) establishment of a heterochronism between the nerves and the muscles, due, always, to an increase in the chronaxie of the muscle.

In hemiplegic patients the chronaxie of the pyramidal tract may rise from 6 to 20 times the normal value. This means that heterochronism is substituted for isochronism between the central regions and the motor tract, which results in the disturbance of motor functions.

For lead poisoning it is claimed that chronaxic tests constitute the most reliable basis for early diagnosis. The radial nerve shows a decrease in chronaxie which is associated with toxic latency. This fact should be taken into consideration in diagnosing saturnism.

In the field of mental diseases two or three cases may be cited. With patients afflicted with apathy in pseudomongolism, vestibular chronaxie increases in proportion as the degree of apathy increases. During states of continued excitement or stupor in dementia praecox, there is also a marked increase in the vestibular chronaxie. This increase can be partially obliterated if the patient is stimulated with an auditory or cutaneous excitant. These facts lead some authorities to assume that the vestibular chronaxies are connected with emotivity through the medium of the sympathetic nervous system. Schizophrenic and feebleminded patients may show abnormalities in the frontal muscle. Normal patients contract the internal and external fasciculi of this muscle at the same time. The chronaxie of the extensors is approximately twice that of the flexors. But with these patients there may be a constant contraction of the external fasciculus

or a jerky eyebrow and there tends to be isochronism between the two bundles.

Jasper (21, 22, 23) has done some work on asymmetry in bilaterally paired muscles in a study of neuromuscular organization in cases of stuttering. He assumes: (1) a lower chronaxic value in the right muscle of a homologous pair of muscles in subjects who are definitely left handed if the activity of the nervous centers tends to reduce the chronaxie of the peripheral muscles in normal human beings; (2) variations in peripheral chronaxie associated with changes in activity of central nervous connections including disturbances of the flexor-extensor ratio in cases where there is a more severe decrease. He finds that symmetrical nerves have unequal chronaxies under normal conditions but when the subordinating action of the centers is removed, their chronaxies become equal. This, he assumes, is possibly the basis of handedness. Dominance in unimanual activities is a function of the degree of subordination of the peripheral neuromuscular mechanisms. After putting this hypothesis to an experimental test with groups of right handed, left handed, and stuttering individuals he finds only partial confirmation. The shortcoming is partially due to the fact that any differences in chronaxic measurements which one might attain at a given moment, as a result of bilateral asymmetry in nervous organization, are likely to be masked off by other dominant physiological relationships prevailing at the time.

Psychology

Emotion. A few experiments on chronaxie have dealt with phenomena of a definitely psychological nature, among which is emotion. Bourguignon (11) finds that the chronaxie of the vestibular nerve is correlated with emotivity. Subjects with smaller vestibular chronaxies, 12σ to 16σ, are emotive while those with larger chronaxies, 17σ to 22σ, are calm. In the same subject, the chronaxie varies with the degree of emotionality. It is his opinion that the vestibular functions enter into emotion through the intermediary of the sympathetic system.

Determination. One study (Altenburger and Kroll, 1) deals with the influence of determining tendency upon certain chronaxies. The determination was established in normal subjects by suggestion. Chronaxie of skin receptors showed a change of 10 to 130 per cent of the initial value at pressure points and of 50 to 300 per cent at pain points after hyperesthesia or hypoesthesia had been suggested simultaneously with the administration of an indifferent medication.

For light the absolute threshold of the eye showed similar changes in chronaxie when the suggestion was given that the subject would have better vision along with the application of a few drops of an indifferent drug to the eye. In all cases the rheobase remained constant. In patients in whom a part of the sympathetic nervous system had been removed by operation, the influence of suggestion shown in normal cases was not manifest in the areas of the skin deprived of the supply of sympathetic fibers. Rather, the results were paradoxical; that is, the suggestion that perception would be better was followed by longer chronaxies and *vice versa*. Similar results were obtained for the visual function after the cervical sympathetic chain had been extirpated. It is concluded by the authors that not only are there elaborations of afferent impulses through suggestion but that it sets into action a mechanism which governs the excitability of the receptor through the sympathetic nervous system.

Interpretation

There has been a vast amount of experimental work done on chronaxie, but little, if any, of it has been directed toward the solution of problems of psychology. Therefore, the results from a psychological standpoint are too scattered to warrant other than the most general suggestions. However, a few interpretations have been advanced.

Lapicque holds that the qualities pleasantness and unpleasantness in affective experience can be accounted for, physiologically, in this way. Nerve impulses usually follow pathways which are isochronous. If the stimulus is strong or if it is continued, the impulse may be 'forced' along pathways which are heterochronous. When an impulse travels a heterochronous route, the experience is unpleasantness and the greater the degree of heterochronicity the greater is the unpleasantness. Pleasantness in a sense is the absence of unpleasantness in an experience. (The writer is of the impression that Piéron has somewhere expressed a similar notion but cannot give the citation. If such be the case, the minor difference between the two viewpoints is that Piéron holds that pleasantness is the result of isochronous functioning, the greater the amount of isochronicity the greater the degree of pleasantness.)

Discreteness in sensory experience may come in for a share of enlightenment in chronaxic terms. Piéron (**50**) is of the opinion that selectivity in the retina may be accounted for somewhat in this way. There is a syntonization between the cone cells at a given

location on the retina, the chromatic neurones of the optic cord, and the dominant light wave. The syntonization is probably due to the peculiar chronaxic coefficients of the nerve elements involved and to modifications of the nervous impulse as they are related to the length of the dominant wave. It would appear in addition that with a slight elaboration of his notion of irradiation one could say that just noticeable differences in experience might be due to the bringing in of new myoneural patterns as a result of the shifting of chronaxic relationships in the functional segments involved. Each new discrete difference may be correlated with the addition of new segments which are slightly heterochronous with the segments producing the previous experience but which are 'forced' to function with them by increment in the intensity of stimulation. In other words, each difference corresponds to the increment of intensity just necessary to bring into the functional pattern the neuromuscular pattern most nearly isochronous with those producing the preceding experience. Or, let us consider the same point from a slightly different angle. In a stimulus series, each step of intensity might affect a neural path whose chronaxie is distinct from that of pathways aroused by other intensities. So, as we pass from one intensity to another, new isochronous neuromuscular pathways are caused to function and each gives rise to a new experience. This concept is supported by the data from a lifted weight experiment. After lifting a weight the chronaxie of the muscle concerned is increased and the increase is approximately proportional to the amount of weight lifted. In the weight series, W_1 would set into play certain functions whose chronaxic values were a certain amount and would give rise to experience E_1, while W_2 would elicit processes whose chronaxic values were sufficiently different from those of the first function to give rise to a distinct experience, E_2.

According to Kucharski, there is an intimacy between vibratory frequency of auditory stimulus and chronaxic properties of the neurones put into play, which accounts for the selectivity in audition. The temporal aspects of the auditory mechanism, as has been pointed out, should be taken into consideration in forming a theory of audition.

In the fields of psychiatry and clinical medicine more specific experimental data are available than for any other realm. From the data of Lapicque and those of Bourguignon, certain laws of neuromuscular functioning have been worked out which are helpful in diagnosing pathological cases. These may be stated in this way:

(1) Chronaxie as a measure of excitability does not vary with experimental conditions as long as these conditions do not modify the excitability itself. (2) A muscle and its motor nerve are isochronous. (3) Muscles are grouped according to the function they perform rather than by anatomical distribution. (4) All synergistic muscles of the same movement have the same chronaxie and tend to be attacked simultaneously by disease. (5) Antagonistic muscles are heterochronous, the chronaxic ratio between flexors and extensors ranging from 1 : 2 to 1 : 3. (6) In a neuromuscular complex there is a chronaxie of subordination, which is governed by the nerve centers, and one of constitution, which is determined by the structure of the complex itself and is independent of the centers. (7) Closely associated with (6) is the law of repercussion, which says that tissues remote from, but with chronaxies equal to, that of injured or diseased tissue will also be affected by the disease or injury.

Bernard has said that there can be only one system of physiology; physiological laws are constant. In pathology these laws are not modified, but their expression is modified. Therefore, every abnormal reflex is conditioned by the appearance of some abnormal sensory-motor isochronism. The disappearance of any reflex is the result of the disappearance of some normal isochronism. Normal synergisms and antagonisms disappear and abnormal ones come into prominence.

Such phenomena as facilitation, inhibition, and irradiation might be better understood with further investigation along chronaxic lines. Lapicque (**25**) claims that inhibition is readily explained in chronaxic terms. It is due to differences in the chronaxie of muscle and nerve. In the reflex the extensors must not contract at the same time as the flexors. But the extensors are really in a state of tension due to slight nervous activity, even during periods of rest. At a moment of flexor contraction there is inhibition of the extensor tone. This is due to the modification of chronaxie of some of the fibers innervating the extensors. Similarly, all inhibition is the modification of chronaxies so as to produce temporary disjunction in the elements concerned.

According to Piéron (**50**), facilitation might be accounted for by a modification of chronaxie of different elements, which are out of syntony with each other, so as to bring them into a functional relationship. Along with this should be considered the results of Brown (**50**). He found that when the motor points of the cortex were stimulated, the excitability of neighboring connected regions

was increased. But this influence was lost if the association fibers between the two regions were sectioned.

In the field of integration, chronaxic methods give some promise of throwing light on the physiological processes involved. One might assume that in the learning of an act of motor skill there is demanded the functional relationship of two or more neuromuscular segments between which there is some degree of heterochronism. The task is done with difficulty or not at all at first. Due to increased strength or much repetition of stimulation the segments are 'forced' to function together. Or, in the case of continued failure, the organism may become emotionally aroused and chemicals from glands may be thrown into the system which bring about the requisite degree of isochronism for a functional relationship. Or, the subject may assume certain motor postures which, through the mechanism of subordination, may bring about the required effect. In memory one could assume that the isochronisms, set up during the learning phase, persist after the activity is discontinued. In forgetting, these forced or newly created isochronisms break down, due either to a supposed instability of the syntony established, or to inability of the organism to reinstate the requisite posture or attitude. In aphasia the patterns of isochronism established in learning language functions, for example, would be disrupted by traumatic conditions and recovery would involve the establishment of new patterns.

When we come to determining tendencies or purposive behavior, psychological theory in terms of chronaxie holds some promise, especially for those psychologists, who, like Hoisington (19), assume that the basis of determination is muscular set or tension. As has already been pointed out, the posture of a member does modify the chronaxie of the cortical centers controlling that member. When an organism functions in a given way there are certain postures assumed. Definite groups of muscles are brought into play. These postures become integrated with the total experience. The organism, then, by assuming the necessary set or attitude, can facilitate the establishment of isochronous neuromuscular patterns necessary in performing the task in question. The same thing is true concerning the rôle of determining tendency in ideation. Let us assume that an idea has as its central core the sensory experience arising from a pattern of muscular contractions involved in the response. The arousal of an idea and the sequence of ideas could be accounted for in terms of the setting up of isochronous neuromuscular patterns through the reinstatement of muscular sets functioning in the original experience.

A rather pretty experiment should be possible in which the object would be to determine the relation between neuromuscular chronaxies and the degree of relaxation. Jacobson (20) has shown that ideational processes cannot function when there is an approximation to complete relaxation of the skeletal musculature. What happens to the chronaxies of these muscles? One would expect that they are modified considerably. It should be possible to determine the chronaxie of different muscular groups which function in varying degrees in a response. One would suppose that these chronaxies would vary as the muscular patterns shift from posture to posture.

With the proper experimental set-up some light might be thrown on the rôle of muscular contractions in activities where a general set has to be maintained for a time while at the same time the organism is responding in terms of minor determinations. This would be comparable to the behavior of an animal in the alternation or the delayed response problem. Is there any correlation between the chronaxies of substances of the neuromuscular complex alleged to be concerned with phasic aspects of contractions and the gross response demands made upon the organism? Likewise, is there any relation between chronaxies of those substances which are alleged to be concerned with the tonic aspects of contraction and responses the organism is required to make?

As has been indicated before, the data on chronaxie thus far answer definitely no questions concerning psychology. This has not been the purpose of any of the research done on chronaxie. Nevertheless, the results are so intriguing, and they come so close to opening up some of the hidden facts concerning the physical correlates of mind, that it seems that, if a program of research could be worked out with definite psychological objectives combined with chronaximetric technique, the results should be very fruitful indeed. In the words of Bourguignon (12, p. 336), " We hope that that which has already been done will encourage researchers to explore territories still unexplored ", especially in the field of psychology.

BIBLIOGRAPHY

1. Altenburger, H., und Kroll, F. W., Suggestive Beeinflussung der Sensibilität. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1930, **124**, 538–552.
2. Boring, E. G., *A History of Experimental Psychology.* New York: Century, 1929. Pp. 699.
3. Bourguignon, G., Modifications de la chronaxie des muscles squelettiques et de leurs nerfs, par répercussion de la lésion de neurones auxquels ils sont fonctionnellement associés. *C. r. Acad. sci.*, 1922, **174**, 773–776.

4. Bourguignon, G., Démonstration d'une table pour la mesure de la chronaxie chez l'homme et chez les animaux. Expérience de mesure de la chronaxie normale du nerf vestibulaire de l'homme. *J. Physiol.*, 1929, **90**, 295.
5. Bourguignon, G., Électrode impolarisable biauriculaire pour la mesure de la chronaxie du nerf vestibulaire. *C. r. Soc. biol.*, 1929, **101**, 1057–1058.
6. Bourguignon, G., La Chronaxie: definition et notions générales. *J. méd. fr.*, 1931, **20**, 299–305.
7. Bourguignon, G., La chronaxie chez l'homme technique. *J. méd. fr.*, 1931, **20**, 305–313.
8. Bourguignon, G., Introduction a l'étude de la chronaxie en physiologie normale et pathologique et en neurologie. *J. méd. fr.*, 1931, **20**, 313–314.
9. Bourguignon, G., La chronaxie du fasceau pyramidal a l'état normal et dans l'hémiplegie. *J. méd. fr.*, 1931, **20**, 325–327.
10. Bourguignon, G., Relations de la chronaxie vestibulaire avec l'émotivité à l'état normal et dans pseudo-mongolisme et la démence précoce. *C. r. Acad. sci.*, 1931, **193**, 250–253.
11. Bourguignon, G., et Baruk, H., Les chronaxies sensorielles. Le système optique et le nerf vestibulaire. *J. méd. fr.*, 1931, **20**, 327–329.
12. Bourguignon, G., et Bennati, D., Les chronaxies motrices et sensitives en pathologie. Les syndromes chronaxiques. *J. méd. fr.*, 1931, **20**, 329–336.
13. Bourguignon, G., et Bennati, D., Chronaxie du nerf, du point moteur et des nerfs intra-musculaires dans les répercussions expérimentales chez lapin. *C. r. Soc. biol.*, 1931, **107**, 223–225.
14. Bourguignon, G., et Déjean, R., Chronaxie normale du nerf vestibulaire de l'homme. *C. r. Acad. sci.*, 1927, **184**, 1349–1351.
15. Bourguignon, G., et Humbert, R., La Chronaxie et les fonctions musculaires. Physiologie normale. *J. méd. fr.*, 1931, **20**, 315–319.
16. Bourguignon, G., et Laugier, H., Modifications expérimentales de l'excitabilité par répercussion réflex chez l'homme. *C. r. Soc. biol.*, 1923, **88**, 265–270.
17. Bourguignon, G., et Radovici, A., Les chronaxies sensitives et les lois des réflexes. *J. méd. fr.*, 1931, **20**, 320–325.
18. Fredericq, H., Testing Excitability by Means of a Time Factor. *Physiol. Revs.*, 1928, **8**, 501–544.
19. Hoisington, L. B., *Psychology.* New York: Macmillan, forthcoming.
20. Jacobson, E., *Progressive Relaxation.* Chicago: Chicago Press, 1929. Pp. 429.
21. Jasper, H. H., A Laboratory Study of Diagnostic Indices of Bilateral Neuromuscular Organization in Stutterers and Normal Speakers. *Psychol. Monog.*, 1932, **43**, 72–174 (Vol. 15, Iowa Studies). Also thesis, U. of Iowa Library.
22. Jasper, H. H., L'action asymétrique des centres sur la chronaxie des nerfs symétriques droit et gauche la grenouille. *C. r. Soc. biol.*, 1932, **111**, 376–378.
23. Jasper, H. H., L'action asymétrique des centres sur la chronaxie des nerfs symétriques, droit et gauch, chez les mammifères. *C. r. Soc. biol.*, 1932, **111**, 702–704.

24. KUCHARSKI, P., Le role du temps dans l'excitation auditive. *J. de psychol.*, 1927, **24**, 83–85.
25. LAPICQUE, L., Chronaxic Switching in the Nervous System. *Science*, 1929, **70**, 151–154.
26. LAPICQUE, L., *L'excitabilité en fonction du temps. La chronaxie, sa signification et sa mesure.* Paris: Presses universitaires de France, 1926. Pp. 371.
27. LAPICQUE, L., Has the Muscular Substance a Longer Chronaxie than the Nervous Substance? *J. Physiol.*, 1931, **73**, 189–214.
28. LAPICQUE, L., On Electric Stimulation of Muscle Through Ringer's Solution. *J. Physiol.*, 1931, **73**, 219–246.
29. LAPICQUE, L., Retrograde Polarization, a Theory of Systematic Errors in Measurements of Muscular Chronaxie through Ringer's Fluid or with Large Electrodes. *J. Physiol.*, 1932, **76**, 261–281.
30. LAPICQUE, L., Alpha and Gamma Curves in Slow Muscles. *J. Physiol.*, 1933, **78**, 381–404.
31. LAPICQUE, L., Neuro-muscular Isochronism and Chronological Theory of Curarization. *J. Physiol.*, 1934, **81**, 113–145.
32. LAPICQUE, L., et LAPICQUE, M., La chronaxie de subordination: sa régulation réflexe. *C. r. Soc. biol.*, 1928, **99**, 1947–1949.
33. LAPICQUE, L., and LAPICQUE, M., Chronaxie of Subordination as Determined by Posture. *Amer. J. Physiol.*, 1929, **90**, 423–424.
34. LAPICQUE, L., et LAPICQUE, M., Le complexe neuro-musculaire présente-t-il deux chronaxies distinctes? *C. r. Soc. biol.*, 1931, **105**, 850–853.
35. LAPICQUE, L., et LAPICQUE, M., Caractère fallacieux des soi-disant mesure de chronaxie effectées dans un bain de solution physiologique. *C. r. Soc. biol.*, 1931, **108**, 719–722.
36. LAPICQUE, L., et LAPICQUE, M., Influence de la grosseur et de l'ecartement des electrodes sur la mesure de la chronaxie musculaire. *C. r. Soc. biol.*, 1932, **109**, 171–175.
37. LAPICQUE, L., et LAPICQUE, M., Sur un prétendu hétérchronisme neuro-musculaire signalé pour les muscles atoniques. *C. r. Soc. biol.*, 1932, **109**, 449–451.
38. LAPICQUE, M., Action des centres encéphaliques sur la chronaxie des nerfs moteur. *C. r. Soc. biol.*, 1923, **88**, 46–47.
39. LAPICQUE, L., et LAPICQUE, M., Modifications des chronaxies motrices périphériques par les centres nerveux supérieurs. *C. r. Soc. biol.*, 1928, **99**, 1390–1392.
40. LAPICQUE, M., Chronaxie de subordination chez un invertébré. *C. r. Acad. sci.*, 1931, **193**, 1037–1039.
41. LUCAS, K., I. On the Conducted Disturbance in Muscle. *J. Physiol.*, 1906, **34**, 51–83.
42. LUCAS, K., II. On the Optimal Electric Stimuli of Normal and Curarized Muscle. *J. Physiol.*, 1906, **34**, 372–390.
43. LUCAS, K., III. The Excitable Substances of Amphibian Muscle. *J. Physiol.*, 1907, **36**, 113–135.
44. LUCAS, K., IV. On the Rate of Variation of the Exciting Current as a Factor of Electric Excitation. *J. Physiol.*, 1907, **36**, 253–274.

45. MARINESCO, G., KREINDLER, A., et FACON, E., Action de l'injection intra-rachidienne de novocaine sur la rigidite parkinsonienne. *C. r. Soc. biol.*, 1930, **105**, 916–919.

46. MARINESCO, G., KREINDLER, A., und JORDANESCO, C., Chronaximetrische Untersuchungen über die Kontraktur nach periphere Facialislähmung. (Ein Beitrag zum physiopathologischen Mechanismus dieser Kontraktur.) *Dtsch. Zsch. f. Nervenhk.*, 1931, **120**, 87–93.

47. MARINESCO, G., et KREINDLER, A., Les modifications des chronaxies musculaires normales et pathologiques produites par des injections de novocaine du point moteur du muscle. *C. r. Soc. biol.*, 1931, **107**, 488–490.

48. MARINESCO, G., SAGER, O., et KREINDLER, A., Études chronaximétriques dans le parkinsonisme post encéphalitique. *C. r. Soc. biol.*, 1928, **98**, 1204–1206.

49. MARINESCO, G., SAGER, O., et KREINDLER, A., Méchanisme de l'action thérapeutique de la scopolamine chez les parkinsoniens post-encéphalitiques. *C. r. Soc. biol.*, 1928, **98**, 1322–1325.

50. PIÉRON, H., *Thought and the Brain.* New York: Harcourt, Brace, 1929. Pp. 116–117, 137–145.

51. RIZZOLO, A., Visual Acuity in Relation to the Excitability of the Cerebral Cortex After Experimental Lesion of the Parieto-Occipital Region. *Arch. di fisiol.*, 1932, **30**, 366–394.

52. RUSHTON, W. A. H., The Effect upon the Threshold for Nervous Excitation of the Length of Nerve Exposed and the Angle Between Current and Nerve. *J. Physiol.*, 1927, **63**, 357–377.

53. RUSHTON, W. A. H., Excitable Substances in the Nerve-muscle Complex. *J. Physiol.*, 1930, **70**, 317–337.

54. RUSHTON, W. A. H., The Normal Presence of Alpha and Gamma Excitabilities in the Nerve-muscle Complex. *J. Physiol.*, 1931, **72**, 265–287.

55. RUSHTON, W. A. H., Nerve Supply to Lucas's Alpha Substance. *J. Physiol.*, 1932, **74**, 231–261.

56. RUSHTON, W. A. H., Lapicque's Canonical Strength-Duration Curve. *J. Physiol.*, 1932, **74**, 424–440.

57. RUSHTON, W. A. H., A New Observation in the Excitation of Nerve and Muscle. *J. Physiol.*, 1932, **75**, 16–17P.

58. RUSHTON, W. A. H., Identification of the Gamma Excitability in Muscle. *J. Physiol.*, 1932, **75**, 161–189.

59. RUSHTON, W. A. H., Identification of Lucas's Alpha Excitability. *J. Physiol.*, 1932, **75**, 445–470.

60. TOLMAN, E. C., *Purposive Behavior in Animals and Men.* New York: Century, 1932. Pp. 463.

THE RORSCHACH INK-BLOT TEST: HISTORICAL SUMMARY *

BY MARGUERITE R. HERTZ

Department of Psychology, Western Reserve University

Developmental Health Inquiry of the Associated Foundations, Western Reserve University

I. Introduction

The study of personality may be approached from two points of view, "global" and "atomistic", as Wells (145) so aptly phrased them. In the former technique, personality as a whole is studied qualitatively, intensively, much depending upon the experience, skill and intuition of the examiner. In the atomistic approach, personality is analyzed into the component traits which lend themselves to quantitative and objective study.

In the last few years, the atomistic approach has received emphasis. Particular traits have been isolated and examined by means of various techniques—questionnaires, rating scales, inventories, batteries of tests, and various instrumental procedures. There are many who claim, however, that such quantitative ratings give no real understanding of the unit-personality (Allport 2, Allport and Vernon 3, Wells 144). They urge systematic inquiry into the nature of the whole personality with more emphasis on the qualitative approach.

In Europe, there has been a notable trend toward a qualitative psychology. The Gestalt School, the "Developmental Psychology" of Krueger (68), the psychology of the eidetic type of the Marburg School (1, 48–50, 55–58), and Stern's "Personalismus" (56) emphasize this approach. The "Cultural Science Psychology" (56, 57, 60) especially, has introduced concepts of "value", "understanding" and "explaining" personality (Dilthey 25, Spranger 128, Stein 129). In like manner, investigators interested in the empirical determination of types, such as Jung (53), Kretschmer (65), Jaensch (48–50), Ewald (31), Birnbaum (48, 49, 56), Rorschach (117), and Roemer (111–116) have shown this influence.

Similar tendencies to admit of subjective values in the appreciа-

* Published through the courtesy of the Richman Fund.

tion of personality may be noted in America. Young (150) and Roback (110) emphasize "values" held by the person; Allport (2) stresses sympathetic understanding of a person's interests and sentiments gained through a kind of "empathy". Whipple (148), Mateer (84, 85), Crane (22), and Reymert (107) point out the value and necessity of qualitative factors in mental measurements. Innumerable investigators have worked with the Free Association Method, one attempt to study personality qualitatively (62). This is probably the most common "characterological" approach in the United States (141).

(A) *The Rorschach Ink-blot Test.* The Rorschach Ink-blot Test is a modification of the free association technique, ink-blots being used as stimuli and a free range of response being permitted the subject. Morgan (92) indicates that it bears a close resemblance to Jung's free association test while others like Soukup (127) and Enke (29) see it as a combination of Freud's dream analysis and Jung's method.

Hermann Rorschach was a Swiss psychiatrist and psychoanalyst who studied the ink-blot technique for years and who conducted many experiments on his patients. He finally selected from a collection of 60 plates, 10 blots upon which he based his test for the diagnosis of personality. Working with these, he collected data, compared and checked what he found with case histories and other material obtained from the clinical and psychoanalytic records of his patients. He reported that he was able to obtain differential response patterns from his various clinical cases.

The preliminary findings of an experiment with the test based on 405 subjects, 231 men and 174 women, of whom 117 were "normal persons" and the others mentally disordered cases, were published in 1921 (117). Here Rorschach explained his method and gave his early results. Responses to the blots were classified in four ways, in answer to the following lines of inquiry:

1. What was the mode or manner of apperception? (*Erfassungsmodi.*)
2. What was the quality lying behind the response? Was it *form, movement* or *color,* or a combination of two or more of these?
3. What was the *content?* What was seen?
4. Was there *originality* in the response?

In each of these divisions, he identified specific test factors from which diagnosis was made.

Rorschach claimed that his test factors pointed to certain psychological processes and that definite symptomatic values could be credited according to their frequency, sequence, and reciprocal relationships. Scores for the various test factors in summary form gave the "psychogram", which served to present the individual as a whole. The interpretation of the psychogram depended not so much on the single test factors as upon the interrelated and combined factors. These latter reflected the intelligence and the affectivity of the individual.

Thus the Ink-blot Test could probe the total personality, revealing intellectual and non-intellectual traits and the reciprocal influence of the one upon the other. Traits such as emotional stability and instability, adaptability, stereotypy and originality of thinking and of living, and others might be brought to light and studied in terms of the whole personality. Personality types (*Erlebnistypen*) might be differentiated as to the degree of "introversive" and "extratensive" traits present: the introversive, the extratensive, the ambiequal, the constricted, and the dilated. These types would have different characteristics in respect to affective qualities, intelligence, psychopathological correlates, imagery, mobility and expressive movements, interests, potential talents, occupational and artistic tendencies, and philosophy of life.

Rorschach realized that his work was of an empirical character and that his data were far from conclusive. However, his success in working out diagnoses of the most differentiated personalities stimulated him to further investigation. He died soon after publication of his article. His monograph "The Application of the Interpretation of Form to Psychoanalysis" was published posthumously with additional comments by Oberholzer (**119**).

Great interest in the test has been expressed since the advent of Rorschach's first publication. Work with it has been continued in Europe and it has been widely applied in the fields of abnormal psychology, psychiatry, psychology of perception, mental testing, and personality work. In the United States, Levy (**72**), Beck (**5–9**), Wells (**144, 145**), and Hertz (**46, 47**) have worked with the technique. Wells (**144**) is of the opinion that, despite the immaturity of the test, it surpasses all other techniques devised to date in "directness of approach to temperamental qualities, in freedom from cultural factors or in the attempt at thorough grounding in descriptive psychology".[1] Similarly, other investigators feel that the Rorschach

[1] Wells, F. L., *Personality Traits*, Appendix D, p. 9. Conference on Individual Differences, Dec., 1930.

Test offers the most promising qualitative approach to the study of personality. It is qualitative in that a large measure of subjective estimate, "evaluation", and "understanding" is necessary in the interpretation of results.[2] Further, this interpretation must be made in terms of the total personality picture. In addition, the test is, in a a measure, quantitative in that frequency tables must be utilized in the interpretation of the scores. The test, therefore, may be considered as a union of the qualitative and quantitative approaches to the study of personality, a happy attempt to reduce to quantitative formula that which has received only qualitative analysis.

(B) *Subsequent Work on the Rorschach Test.* A second edition of the manual has appeared in two volumes (**118**) which includes the original study (**117**), Rorschach's picture, a biography by Morgenthaler, bibliography, and a reprint of his second article (**119**).

II. Technique of the Rorschach Test

(A) *Administration.* The Rorschach method is described and elaborated by Behn-Eschenburg (**10**), Enke (**28**), Soukup (**127**), Müller (**94**), Oeser (**100**), Löpfe (**79**), and Loosli-Usteri (**75**). Binswanger (**13**) discusses the philosophical assumptions upon which the test is based. Müller (**94**) takes up the technical aspects of the test, summarizes and evaluates the work done. Short descriptions of the test appear in Kronfeld's text (**67**) and Maller's review (**83**). Salas (**120**) publishes a part of a monograph in preparation, describing the method, its difficulties, and the results obtained for normal cases. Beck (**6, 7**), Hertz (**46, 47**), and Vernon (**135–137**) give comprehensive surveys of the literature and detailed descriptions of the administration, the scoring, and interpretation of the responses.

Photographs of the blots are shown in the publications of Loosli-Usteri (**75**), Löpfe (**79**), Pfahler (**102**), and Wertham and Bleuler (**147**). The blots in black outline, the respective colors being written on the figures, are given by Oberholzer (**119**). A sample for Card III appears in Vernon (**135**). Other series of blots applied like the Rorschach are given by Behn-Eschenburg (**10**), Struve (**130**), Roemer (**111, 112**), Gordon and Norman (**43**), and Weil (**143**). Giese (**40, 41**) prefers Roemer's revised series because they lend themselves to greater objective and quantitative treatment.

[2] The Rorschach symbols, abbreviations and formulæ herein used are those employed at the Brush Foundation (now called the Developmental Health Inquiry of the Associated Foundations), Western Reserve University. They are the English equivalents which have been adopted.

Müller (94), however, objects to any change of material and insists upon strict adherence to the original blots. Written descriptions of the blots translated directly from the original manual appear in Beck (7) and Oeser (100).

The directions for administering the test are described by Rorschach (117, 118), Rorschach and Oberholzer (119), Loosli-Usteri (75), and Beck (5–9), all of whom try to retain the original instructions. Pfahler (102), Juarros and Soriano (51), Oeser (100), Hertz (46), and Vernon (135) likewise describe the procedure with slight changes in the instructions given the subject.

Most investigators agree with Rorschach that the test is easy to administer. Mira (89), Juarros and Soriano (51), and Pfister (104) report difficulty with abnormal subjects. Oeser (100) observes some antagonism on the part of his " color-reactors "; Vernon (135) observes likewise with some of his adult subjects. Loosli-Usteri's children under thirteen years of age (78) could not appreciate the " meaninglessness " of the blots. Hertz (46) observes that the attitude, especially to the first card, influences the reactions and therefore she introduces a trial blot before passing to the regular series. Löpfe (79) and Vernon (135) emphasize the importance of the attitude in determining the nature of the responses.

Most examiners follow Rorschach in giving unlimited time to each subject. Löpfe (79) limits his subject to seven responses for each blot. Hertz (46) limits the time to two minutes per picture, not including time for instructions, explanations and discussion, in order to standardize conditions of the test. Vernon (135) disapproves of such curtailment because it " prejudices the situation ".

In recording responses, Rorschach is generally followed in that answers are written down verbatim and the exact parts of the blots selected for interpretation are indicated. Many examiners use tracing sheets. Loosli-Usteri (75) uses the " V " in different positions to indicate the position in which the card is held, the point always corresponding to the top of the card. Vernon (135) recommends prepared mimeographed diagrams on which each response can be written at the appropriate place, each response being numbered. Hertz (46) reports success with prepared diagrams traced in black and colored ink from the original series, on which are written symbols, letters and numbers, arbitrarily assigned to different parts, which are used in recording responses.

(B) *Scoring of Responses.* Most investigations include in more or less detail the Rorschach categories with their respective symbols

and meanings. Most foreign studies use the original German symbols. Loosli-Usteri (75) employs the French equivalents; Wells (145), Beck (7), Hertz (46, 47), Wertham (147), and Oeser (100) the English, but unfortunately these latter are not identical. Vernon (135) adheres to the German.

The usual procedure advocated is to refer to the original manual (117) and to Oberholzer (119), scoring responses by comparison with suggestions and samples in these publications. Examiners also question their subjects as to the factors behind their responses, form, movement, or color. Müller (94) recognizes the limitations of this procedure but warns against independent determinations without recourse to the available standards. Furrer (36) outlines certain criteria for scoring the movement responses; Munz (96) offers suggestions for evaluation of certain factors.

Most investigators agree, however, that much of the scoring is subjective and difficult to determine. Löpfe (79) emphasizes this difficulty. Pfister (104) has difficulty in determining the quality of the response with his mental defectives. Beck (7) experiences difficulty with certain factors despite the assistance he received from Oberholzer who scored ten records which were sent to him. Vernon (135) reviews most of the criteria for scoring and offers suggestions for improving the objectivity and adequacy, emphasizing the need for adequate tabulations of responses of a representative group with the appropriate scoring determined by experts on the test.

In somewhat this manner, Hertz (46) has attempted to standardize the scoring method on the basis of the Rorschach records of 300 Junior High School students. Definite quantitative criteria statistically developed are outlined for certain factors; other qualitative criteria determined by three to five judges are likewise adopted. Tables of responses with their appropriate scores are given, consisting of some 11,000 items of response. The scoring method is found to be reliable as judged by the extent of agreement between the scores of one judge and those of another on 100 records.

(C) *Summary: Administration and Scoring.* 1. Despite increased interest, innumerable investigations on the technical aspects, and extensive application of the Rorschach Test, the procedure in giving the test is still variable and indefinite. Few attempts have been made to standardize the method of administration.

2. Scoring of the responses is still poorly defined and largely subjective, depending upon the experience and intuition of the examiner. Adequate criteria for scoring have not as yet been expounded.

3. A few studies report tables of responses statistically computed. These, however, have not been universally accepted or used.

III. The Reliability of the Rorschach Test

Despite innumerable studies on the test, little thought has been given to the question of reliability. Reference should be made to Hertz (47) for a review of the work done to date on the reliability. Behn-Eschenburg (10), Mira (89), and Wertham and Bleuler (147) claim reliability for the test but offer no statistical evidence. The two statistical studies dealing specifically with reliability offer conflicting results. Vernon (136), using the corrected split-half method, attains low reliability for all the test factors, ascribing his results especially to subjectivity of scoring and to shortness of the test. Intercorrelations of the different test factors as indicated by Rorschach do not hold statistically. Hertz (47) first standardizes the procedure and scoring method and then computes the reliability of the test factors, also using the corrected split-half method. She claims reliability for most of the Rorschach factors, on the basis of coefficients ranging from .9 to .6.

Summary: Reliability. 1. With few exceptions, the reliability of the Rorschach Test has not been attacked.

2. Because of unsatisfactory results Vernon concludes the test is not reliable. Hertz, on the other hand, obtains satisfactory reliabilities for the different factors, ascribing the results to better standardization of procedure and a more objective scoring method.

IV. Norms

(A) *Results in Personality Studies of Children and Adults.* Rorschach (117) published a series of tables containing norms for normal and psychotic groups. He did not include any statistical data, however. Additional norms appear in personality studies of children and adults, generally in terms of averages, means or medians.

Behn-Eschenburg (10), working under the personal direction of Rorschach and interested in the changes taking place in the "Erlebnistypus" during adolescence, summarizes results for 209 children, thirteen to fifteen years of age, selected at random in the *Realschule* and the *Volkschule*. Löpfe (79) publishes results based on the test records of 120 children, aged 10–6 to 12–6, selected from various grades in the *Volkschule* in Zurich and from divers population districts. The test is applied to similar age groups in a Geneva public school by Loosli-Usteri (75) who compares her results with those of Löpfe.

Bleuler (**14**), interested in the problem of heredity versus environment, establishes statistically reliable norms for the different categories on the basis of 200 records from unrelated subjects in order to make comparisons with groups of siblings.

Norms for mental defectives are presented by Pfister (**104**) and Beck (**6, 7**). Kerr's norms (**54**) for 365 children, ages seven through twelve, including mental defectives and clinical cases, will be published shortly. Schneider (**123**) presents results for 80 school children in special classes in his study of intellectually inhibited children. Two Spanish studies by Linares (**73, 74**) are reported, with results for feebleminded, superior, and normal children. Salas (**121**) gives a tentative standardization with references to age groups from five to eight years. Hertz (**46**) computes norms for 300 junior high school children, for the group as a whole and for the group classified according to I.Q. into low average, average, superior, and very superior. Norms are also included for three other groups, *viz.*, clinical cases, maladjusted subjects, and feebleminded subjects.

In a study of the pyknic physique, Munz (**96**) presents norms for 92 subjects, including 28 male adults of superior intelligence. Oeser's study (**100**) of form-color types includes Rorschach results with 32 English adults. Vernon (**136**) publishes his results with 90 adult subjects and summarizes in a table the norms of most of these investigators.

Other studies which include norms will be mentioned in subsequent pages.

(B) *Influence of Age on Rorschach Scores.* Rorschach contended that changes in the "Erlybnistypus" take place at different ages and that scores should show variations with age. Behn-Eschenburg (**10**) reports definite changes at stated periods of development during adolescence but his results are not statistically substantiated. Loosli-Usteri (**75**) likewise reports changes in Rorschach categories with age as the W, D, and %P. She does not state whether these are statistically reliable. Differing from Rorschach, she maintains that movement responses are not normal for ages nine through fourteen and that the ambiequal or introversive personality is abnormal in childhood. These conclusions are verified in a later study (**77**).

Norms for the different age groups show little change with age in Löpfe's study (**79**). Individual differences are greater than any

age differences noted. Mira (**89**), testing subjects fourteen to sixteen years of age, reports agreement with Löpfe and Behn-Eschenburg. Linares (**74**) presents results for age differences on the basis of 50 boys and 50 girls.

Mention should be made of Shuey's theoretical article (**125**) in which he differs from Rorschach's contention that the test can show the degree to which education has allowed either the introversive or the extratensive tendency to dominate the personality. Shuey, influenced by the Marburg School, advances the interpretation that behavior is a differentiation process of the nervous system rather than a building up process and the ink-blot test, rather than showing the kind of training received, indicates the degree of integration or differentiation of the perceptual processes.

(C) *Influence of Sex on Rorschach Scores.* Some studies report sex differences, despite Rorschach's observations that the scores cannot reveal such differences. Behn-Eschenburg (**10**), Dubitscher (**27**), and Linares (**74**) report characteristic differences. Struve (**130**), using blots similar to those of Rorschach, reports differences in "invention". Oeser (**100**) confirms Rorschach's conjecture that women are more extratensive than men.

(D) *Influence of Race on Rorschach Scores.* Definite differences between Geneva children and Zurich children (tested by Löpfe) are observed by Loosli-Usteri (**75**), thus confirming Rorschach in his contention that the "Erlebnistypus" is different for different racial groups. Because of these differences, the author emphasizes the necessity for using norms appropriate to the race and locality of the subjects.

(E) *Heredity.* Bleuler (**14**) reports the Rorschach technique to be a reliable diagnostic instrument and excellent for demonstrating the existence of family similarities. He compares the Rorschach records of 49 groups of siblings variously selected with similar age groups of unrelated subjects. Statistically reliable differences are established. He confirms his conclusions in a later article (**15**). Verschuer (**139, 140**), comparing 23 pairs of like twins with the same number of unlike twins, ages ten to twenty, concludes that the mental traits which the test purports to indicate are due to hereditary factors.

Although no results pertaining to the Rorschach test are reported, Koehn (**61**) uses a few of the Rorschach blots in his battery of tests given to monozygotic and dizygotic twins. Bleuler (**15**) likewise

uses this approach, and reports greater similarity of scores among the identical twins than among the others, showing, as he claims, the influence of heredity.

(F) *Summary: Norms, Age, Sex, Race, Heredity.* 1. Norms for various groups of children and adults have been published. They agree to some extent with the tentative norms published by Rorschach.

2. Norms are still grossly inadequate. The groups upon which they are based are generally small and not representative. Hence the norms often show many disagreements for similar age groups. They are not comparable, however, because of the variety of criteria and scoring methods employed, because of lack of adequate standards, and because of variable factors such as race, social and economic status, etc.

3. The contention that age influences scores has not been adequately and statistically verified.

4. Sex differences in Rorschach scores have not been reliably established.

5. Racial differences are reported in one study (Loosli-Usteri) but the reliability of these differences is not given.

6. Rorschach psychograms show greater similarity between siblings than non-siblings, and between like twins than unlike twins. Conclusion is made that the technique may be used to show the influence of heredity versus environment on personality make-up.

V. Validity of the Rorschach Ink-blot Test

(A) *Diagnosis of Intelligence.* Rorschach claimed that his ink-blot test reflects levels of intelligence. In his manual he provided tables showing the incidence of the various factors at different levels. Subsequent investigators agree that the test is a good instrument for gauging intelligence and for detecting feebleminded individuals. Müller (**94**), for example, claims that the test can diagnose intelligence better than the Binet Test but he gives no statistical evidence for this assertion. Most of these claims have received little quantitative validation. Rorschach's contention that his divers test factors are not to be construed as statistical variables but rather as component parts of the whole psychogram, has no doubt discouraged psychometic procedure in this direction.

(1) *Validation by group comparison.* A few investigators have, however, attempted to substantiate these claims statistically. Some have taken different groups, compared them, and noted the differences in the Rorschach patterns.

Munz (**96**) obtains characteristically different responses for groups of average subjects (63 Ss) and highly intelligent subjects (28 Ss) made up of professional men and the like. Mira (**89**) claims to substantiate Rorschach's norms by his results with 19 superior, 31 average, and 13 uneducated adults. Differences are likewise reported by Schneider (**123**) who compares 27 good pupils with 18 poor pupils.

Characteristically different scores are likewise reported by Dubitscher (**26**) for superior and inferior subjects, 90 in all. Linares (**73**) includes in his study Rorschach results for feebleminded and superior children, classified on the basis of the Spanish adaptation of the Stanford-Binet Test. For a superior group of 39 adults, Beck (**9**) reports an unusually high number of answers and likewise observes that different types of "associational activity" characterize this group.

Vernon (**137**) compares his three groups of somewhat different cultural levels. He detects differences in the absolute numbers for many of the test factors, but when he computes the percentages of each in reference to the total number of responses given, the differences disappear, with the exception of %P which is statistically reliable.

Dividing 300 subjects into four groups on the basis of I.Q., 30 low average, 115 average, 79 superior and 76 very superior, Hertz (**46**) shows differences in the average test factors for each group, but the variability is so pronounced that the differences are not considered reliable. The %F+ is sufficiently reliable, however, to permit of its use in differentiating the lowest fringe of the low average group and the uppermost fringe of the very superior group.

Psychograms of mental defectives are presented by Pfister (**104**), Juarros and Soriano (**51**), Gordon and Norman (**43**), Linares (**73**), Kerr (**54**), Beck (**6, 7**) and Hertz (**46**).

Pfister (**104**), with 59 cases, claims to verify many of the Rorschach indices of intelligence and affectivity. He cannot, however, validate the oligophrenic detail factor which Rorschach considered indicative of mental deficiency. He concludes that the test can not only diagnose different grades of deficiency but can also reveal certain peculiarities of this group. Many of his findings are verified by Beck (**6, 7**) who investigates the incidence of the Rorschach factors at various levels of mental development among 69 feebleminded children. Comparing the mean response at each mental age for all factors, he too claims to confirm Rorschach in

many respects. Though he gets some of the elements in the typical Rorschach pattern, many deviations are evident. These he explains in terms of "personality factors" which "complicate the picture".

On the basis of the records of 50 mental defective and problem cases Juarros and Soriano (**51**) publish results which appear to substantiate Rorschach although their norms are higher than his. Little statistical data are included, however. Kerr (**54**) reports norms for 100 mental defectives which confirm many of the findings of Beck and Loosli-Usteri. An unpublished thesis of Ganz (**39**), reported by Vernon, shows no differences in the W, M, or Sum C factors in a group of 43 defectives as compared with normal subjects.

In a statistical study by Hertz (**46**) reliable differences in many of the test factors are found between a normal and subnormal group. A Rorschach pattern is obtained which substantiates the original picture in many ways. Again the Do does not distinguish the groups reliably.

Reference should be made to Gordon and Norman (**43**) who use three blots similar to Rorschach's in an experiment on perceptual configurations which underlie speech in mental defectives. Differences are reported in terms of number of associations and color responses between high grade and low grade defectives but these only partially substantiate Rorschach.

(2) *Validation through correlation with other criteria of intelligence.* Attempts have been made to substantiate Rorschach's test as an index of intelligence by correlating the test factors with other criteria of intelligence. Investigators like Müller (**94**) argue against this procedure on the claim that Rorschach's approach is predominantly qualitative and that quantitative scores are secondary and of little value except in relation to the total psychogram.

Mira (**89**) correlates a score of a test of "visual imagination" with Rorschach factors, reporting no correspondence with number of responses and $+0.38\pm0.05$ with %O. He likewise reports $+0.52\pm0.03$ between W and an intelligence test score. Schneider (**123**) uses his own scale for W, M, %O and %F+ instead of the original scores and obtains correlations of $+0.42$ to $+0.53$ between his composite ratings and Binet and group intelligence scores, results which appear to validate Rorschach's claim.

Reference has been made to Beck's study (**6, 7**) in which he compares successive mental age groups and correlates mental development as measured by the Stanford-Binet Test with the Rorschach indices. Results range from $+.012$ (for R and also for Sum C) up to

+.64 (for F+). With the exception of F+ and W, his coefficients are less than .40.

Vernon (137) uses a composite score derived from various intelligence tests, scholastic grades and ratings as an index of intelligence. Correlations with Rorschach factors are most unsatisfactory. With the exception of %F+ which correlates +0.33 with grades and +0.43 with ratings, and %M which correlates +0.32 with intelligence, his figures are insignificant. The %F+ likewise attains a comparatively high correlation in Hertz' study (46) in which Rorschach factors are correlated with I.Q. as indicated by the Otis Self-Administering Intermediate Test. Results of +.460±0.33 for %F+, −.420±.038 for Do, +.398±.032 for %O+, −.351±.035 with %Dr (computed without consideration of the Do category) are obtained. Other figures are insignificant. Computing the multiple correlation, a battery of test factors is obtained yielding a correlation of +.556 with the criterion. This permits the conclusion that the test factors arranged in battery form and weighted accordingly afford some measure of intelligence but not enough for prediction.

Mention should be made of the study of Reymert and Hartman (108) in which the Rorschach Test, employed as a test of "imagination", correlates zero with the Knox Cube score, this latter purporting to indicate "practical intelligence".

(3) *Validation through case studies.* A few case studies are presented for superior and defective subjects, showing corresponding Rorschach psychograms. Behn-Eschenburg (10), Schneider (123), Löpfe (79), and Beck (5) find such correspondence and conclude that the test can gauge intelligence effectively. Other case studies will be mentioned below.

(B) *Diagnosis of Aptitude and Talent.* Rorschach psychograms were supposed to reflect not only grades of intelligence but kinds of intelligence, potential aptitudes and talents, and vocational interests. Stumberg (131), using the first five and the tenth Rorschach blots as one of many criteria of poetic talent on two groups, 28 in each, one possessing, the other deficient in, poetic talent, reports that the total number of items suggested (a factor which Rorschach did not consider highly significant) differentiates the groups and exhibits certain types of imagination. Attempts to utilize other Rorschach symptomatic categories are without success. Leinweber (71) uses the ink-blots with other tests to analyze the literary creations of eight poets in terms of Jaensch's typology.

Mention should be made of Struve's study (130) of imaginative types with 117 boys and 106 girls, in which he uses a modified form of the ink-blot test consisting of cloud-like blots with three degrees of grayness and a random distribution of high lights. He claims that his blots can distinguish types of intelligence, imaginativeness, and inventiveness. Reference should likewise be made to Koht's study (63) and to that of Ziehen (151) in this connection.

Significant relationships between ambiequality, original responses, and general artistic tendencies are statistically established by Vernon (137), who correlates a composite score indicative of general artistic tendencies with Rorschach factors and combination of factors. Cantril and Allport (19) report a study by Stromwall on the overlapping implications of the typologies of Spranger and Rorschach in which, on the basis of 39 records, subjects with high religious and aesthetic values give more movement, those with high political interests are more extraversive, and those with high aesthetic scores give more detail.

In a study of leadership, Luithlen (82) uses the Rorschach test as a test of imagination in order to study the rôle of phantasy.

Mira and Roemer find the Rorschach test of great value for vocational guidance. Mira (89) has had great success with the test in this direction. Roemer (111–116) extends and elaborates the method and presents probably the most extensive study. The test exhibits for him many personality traits such as attention, discrimination of form and color, self-control, self-confidence, lively and depressed temperament, etc., which figure in vocational ability. The test can therefore discover vocational fitness.

Believing the test valuable in this way, Dériaz (24) includes the ink-blot test in his battery of vocational tests for bar-straighteners. He believes it is of more use, however, when interpreted qualitatively.

(C) *Summary: Diagnosis of Intelligence, Types of Intelligence, Aptitudes and Talents, Vocational Fitness.* 1. Many investigators report ability to differentiate groups in terms of Rorschach response patterns. Superior, average, and subnormal groups appear to give characteristically different psychograms, although statistical reliability of the differences is not always indicated (Munz, Mira, Schneider, Dubitscher, Linares, Beck, Vernon, Hertz).

2. The %F+ and the %O are probably reliable in differentiating a low average group from a very superior group (Hertz).

3. Several investigators report characteristically different patterns among different grades of mental defectives (Beck, Pfister,

Juarros and Soriano, Kerr) but again statistical reliability is not included. Rorschach is substantiated in this respect, although many of his indices of feeblemindedness, especially the oligrophrenic detail, have not been verified.

4. Correlation procedure has not given satisfactory results. Satisfactory correlations of scores and intelligence have been reported for children (Schneider). Beck's correlations for mental defectives are uniformly low. Hertz's correlations for an adolescent group are all below .40, although she does obtain with a battery of test factors a multiple correlation of +.556 with an intelligence test score. Her results indicate some correspondence between %F+, Do, %O, %Dr and intelligence. Vernon's figures are low and unsatisfactory. Conclusion must be made from the data at hand that the Rorschach test factors show low correlations with objective criteria of intelligence, that they cannot serve to predict intelligence, and that they are not as good as other recognized tests of intelligence.

5. The case studies on record illustrating the claim that the Rorschach Test can gauge intelligence are interesting and provocative but have little scientific value.

6. Rorschach's contention that the test can diagnose kinds of intelligence has not yet been objectively validated although there are many cases on record illustrating qualitative differences in intelligence.

7. Comparatively little work has been done on the test in respect to aptitudes and talents. Artistic tendencies (Vernon), religious and aesthetic values (Stromwall), and imagination and inventiveness (Stumberg, Struve) may be revealed by certain of the Rorschach factors.

8. Many investigators testify to the value of the test for vocational guidance (Mira, Dériaz, Roemer) but as yet no objective and statistical validation has been reported.

(D) *Diagnosis of Non-intellectual Traits.* The validity of the Rorschach Test as a means of probing the personality and especially the affective qualities of the individual has been approached by comparing the Rorschach types with other typological systems, by using correlational procedure, by making group comparisons and by comparing Rorschach psychograms with case studies.

(1) *Comparison with other typological systems.* Considerable study has been made on the relationship between the *Erlebnistypen* and other typological systems such as those which emphasize various psychopathological traits (Jung), constitution (Kretschmer), expres-

sive movements, such as handwriting (Klages), perseveration (Heymans and Wiersma), eidetic imagery (Jaensch), attention (Kroh), and the like. For summaries in this field, reference should be made to Pfahler (102), Willemse (149), Wertham (147), Klüver (55, 60), Oeser (101), and Allport and Vernon (3). Theoretical discussions on the similarity of Rorschach types with others are given by Neymann and Kohlstedt (97), Oeser (100), Müller (94), Oberholzer (119), and Klüver (55). Vernon (136) probably gives the most comprehensive account of the work done to date in reference to the Rorschach types.

Since the *Erlebnistypen* depend upon the prevalence of introversive and extratensive tendencies in the personality, attempts have been made to compare these types with the introvert-extrovert types of Jung, and to detect their prominence either in the constitutional types of Kretschmer or in various psychotic groups (97, 100). Müller (94) cautions against such quick identification among them. Rorschach and Oberholzer (119) explain the essential differences between them, and Klüver (55) distinguishes between empirical determinations in types and logical generalizations.

Vernon (136) reports no agreement between a composite score obtained from the Neymann-Kohlstedt questionnaire for introversion and extroversion (based on Jung's concepts of these terms) and other measures of "socialty", with Rorschach's (M — Sum C)% scores. He accounts for the unsatisfactory results by emphasizing Rorschach's contention (reiterated by Müller) that the isolated factors are not intended to be treated statistically.

Assuming, as did Allport and Bender (11), that extroversion tends to correlate suggestively with ascendance-submission, Hertz (46) correlates scores on the Brush Modification of the Allport Ascendance-Submission Test with Rorschach introversive-extratensive types. On the basis of 164 subjects, a tetrachoric correlation of .86 is obtained, validating the contention that predominance of color indicates ascendant qualities and excess of movement, submissive qualities.

Enke (28) observes that test records of patients suggest a correspondence between manic tendencies and extratension, schizoid tendencies and introversion, to some extent validating the claims for the M and C factors. In this connection, Levy and Beck (72) likewise report characteristically differing Rorschach psychograms among manic and depressive patients.

The problem of constitutional types in relation to the Rorschach instrument has been investigated by Munz (96) and Enke (28, 30) in Kretschmer's laboratory. Results show the pyknic type corresponding to the extratensive type and the "schizaffin" to the introversive. Munz also observes differences in the attitude of his groups toward the test and in the content of their interpretations. He concludes that the Rorschach technique is especially valuable in examining the affectivity of the individual and in uncovering the schizoid and "syntonic" components of his personality. Enke (29) likewise discusses the significance of the test in psychotherapy.

In a study of 89 prisoners for Kretschmer types, Mohr and Gundlach (91) include the Rorschach Test in their series of measurements. Although they use the test very "roughly", they claim their results are suggestive of the relationships observed here. Dubitscher (26) examines the Rorschach results in his groups of 190 subjects of whom 90 are normal and the others are persons with nervous disorders, psychopaths and hysterics, classified according to constitutional types. Cycloid subjects and normal pyknics give similar responses; likewise the asthenics and the schizophrenics. The *Erlebnistypen* of the different constitutional types resemble those of certain psychoses, he observes. Dubitscher concludes from use of the test that it is more valuable when applied qualitatively.

Poppinga (105) and Oeser (100) study the Rorschach test in connection with form-color types, originally associated with Külpe (69). For a description and historical survey of the work done with these types, reference is made to Poppinga (105), Wertham (146), and Oeser (101). In these studies, subjects are classified into Form Reactors (F), Form-Color (FC), Color-Form (CF), and Color Reactors (C), on the basis of the percentage of form reactions given. Poppinga (105) compares such form-color types with the *Erlebnistypen*. Oeser (100) likewise classifies 32 students, after examining them tachistoscopically, and reports definite differences between pure color and pure form abstractors. He confirms his findings by using the Rorschach test to analyze temperamental traits. No similarity can be observed between form-color types and Rorschach introversive-extratensive types, however. Vernon (136) studies and rearranges Oeser's data and reports considerable resemblance between the form-color types and Rorschach's coartative-extratensive types. Claim is made by Pfahler (102), who examined seven subjects with three of the Rorschach blots,

that there is agreement between certain typological characteristics and the Rorschach psychograms.

Investigators have likewise studied the relationship between Jaensch's integrated and disintegrated types (**2, 53, 54, 66, 67**) and the Rorschach types. Weil (**143**), using the Rorschach blots with other blots, reports that integrate subjects only (characterized by rapport with outer world) are able to perceive meaningful-wholes. O. Mueller (**95**) likewise observes by use of tachistoscopic tests with pictures and Rorschach blots that integrates give connected wholes and are more subjective and synthetic while disintegrates are more analytic and objective. Comparing *Erlebnistypen* with eidetic types, Schenck (**122**) finds that the J-1 type corresponds to the ambiequal with a tendency toward extratension while introversives belong to the J-2 type and coartatives to the disintegrate type. Statistical data are lacking in most of these studies, however.

Oeser (**100**) and Poppinga (**105**) conclude from their work that color reactors correspond to the J-1 integrate type, form reactors to the disintegrate type, sometimes to the J-2 inner integrated type. Bryn (**17**) observes distinct differences in the Rorschach scores in two groups of integrates and disintegrates classified according to certain tests of spatial perception.

Erlebnistypen have been studied also in relation to handwriting. Halvorsen (**45**) correlates the average angle of slope of handwriting of 143 subjects with the ratio of $\frac{M}{\text{Sum C}}$ computed from the Rorschach scores. His correlations are highly satisfactory, averaging +0.60, showing that traits accorded to these different angles of script correspond to the introversive and extratensive types. Vernon (**136**) cannot verify any of these conclusions but reports that experiments conducted by M. Bleuler and R. Saudek show definite agreement.

(2) *Clinical validation.* Innumerable investigators testify to the clinical possibilities of the test: Binswanger (**13**), Bumke (**18**), Dubitscher (**26**), Enke (**29**), Eyrich (**32**), Flugel (**33**), Fränkel and Benjamin (**34**), Kretschmer (**64, 66**), Lange and Kraepelin (**70**), Levy and Beck (**72**), Lowrey (**80, 81**), Matzkevitch (**86**), Meggendorfer (**87**), Mira (**89, 90**), Morgan (**92**), Müller (**94**), Oberholzer (**98, 99**), Prados and Linares (**106**), Roemer (**111, 113, 114, 116**), Skalweit (**126**), Soukup (**127**), Veit (**133, 134**), Weber (**142**), Wells (**145**), etc. In fact, the test is already used as a psychiatric

diagnostic instrument in many European clinics. Validation of claims made has been, for the most part, in terms of comparison of groups of known character or by qualitative studies. A few attempts at correlational technique have been employed.

(2a) *Comparison of groups.* Behn-Eschenburg (**11**) observes characteristic differences in the psychograms of "Realschuler" and "Volkschuler" and claims to be able to differentiate children whose psychograms approach those of adult psychotics. His results, however, are not statistically determined. Loosli-Usteri's comparison (**75**) of asylum children with those living at home indicates definite peculiarities in the former group, especially in terms of M, DS, and C. In a subsequent article (**76**), she again detects definite leanings toward abnormality in a group of institutional children. A further comparison (**77**) of 63 boys attending a medico-pedagogical clinic and 63 boys chosen at random in schools confirms her early results, especially the facts that M indicates introversion and represents a stabilizing factor of the affectivity.

Validation of the popular response factor as the index of "thinking in common with thinking of the social group" is reported by both Pfister (**104**) and Beck (**6, 7**). Pfister (**104**), Löpfe (**79**), Beck (**6, 7**), and Vernon (**137**) cannot validate the DS factor on the basis of group differences. For Hertz (**46**), the DS cannot distinguish ascendant and submissive groups, but it does differentiate a maladjusted group from a normal group. Enke (**28**) observes more DS in his schizophrenic patients than in his cycloid group.

Hertz (**46**) compares stable and unstable groups, classified on the basis of the Woodworth-Mathews Total Score, with similar groups classified on the basis of the Rorschach color score, and obtains a tetrachoric correlation of +.66. Conclusion is made that the color score tends to indicate neurotic tendencies and hence the degree of emotional balance. Comparing ascendant and submissive groups, she reports statistically reliable differences for M, C, %A, %O, and P. Comparing stable and unstable groups, she observes reliable differences of the M, %A, %O, and P. Finally, comparing a subnormal, a maladjusted, and a psychoneurotic group, she reports definitely differing Rorschach patterns and statistically reliable differences for %A, % Anatomy, %O+, %O−, %P and DS. Beck (**6, 7**) and Pfister (**104**) failed to validate the color factor by group comparisons; Hertz reports that it cannot differentiate between stable and unstable groups, but it does differentiate between ascendant and submissive groups. For Hertz, the M and C can distinguish normal

from abnormal groups but show no reliable differences among the abnormal groups themselves.

Enke (28) reports characteristic differences between cycloid and schizophrenic patients. Dubitscher (26) observes differences in his groups of normal subjects, psychopaths and hysterics. In another article (27), his results with 100 male adult psychopaths show a reduction in the so-called intellectual factors and an increase in the affective and impulsive tendencies. He likewise reports differences in groups of children, feeble-minded, dull, and psychopathic, in terms of the number of responses. Salas (120) gives results for normal and neurotic children, and later (121) again compares responses of 210 normal subjects with those of neurotics, confirming his findings as objective and statistically reliable.

Binder (12) finds that a new type of chiaroscuro response not dependent on form, "Hd", can differentiate neurotic and psychopathic groups. Pfister (104) observes more chiaroscuro responses in his mentally defective subjects.

Kerr (54) shows differences in clinic and mentally defective children as compared to a normal group in color responses and content of the responses. Meltzer (88) can differentiate stutterers from non-stutterers and reports great success in analyzing the personalities of the former. Veit (133) studies the Rorschach picture of post-encephalitic Parkinsonism in 25 cases and reports that the Rorschach pattern corresponds to the clinical description usually found for this group. Eyrich (32) can diagnose the personality of epileptic children with the Rorschach instrument. On the other hand, Mira (90) and Dubitscher (26, 27) find it impossible to establish typical Rorschach patterns for the mental disorders because of so many variable factors. Mira (90) obtains the same picture for a normal group as Rorschach reported for a schizophrenic group.

It should be mentioned here that studies of the Rorschach characteristics in the types of Jung and Kretschmer likewise belong in this section, since the views of both are based on psychopathological data.

(2b) *Qualitative studies.* Many case studies on record attempt to validate Rorschach's claims clinically. Psychograms are studied in connection with descriptions, reports, behavior notes, and casual or methodical observations of school teachers, psychiatrists and other judges.

Rorschach's original manual (117) contains many short case studies illustrating his observations. His subsequent article (119)

contains a detailed account of his interpretations of an individual who had been psychoanalyzed independently by Oberholzer. A more recent study by Oberholzer (**99**) on the differential diagnosis of the psychic effects after a skull trauma, confirms the diagnostic value of the test.

Reference has already been made to Behn-Eschenburg (**10**) who uses as criteria of validity of his results reports in literature on the psychology of children in various stages of adolescence and also teachers' reports on certain cases. Clinical validation is likewise reported by Mira (**89**) by means of short case studies. Löpfe (**79**) compares psychograms of 42 boys with the uninfluenced reports of teachers confirming, as he claims, many of the Rorschach factors, especially P, O, and %F+. In comparing psychograms with teachers' estimates, he finds agreement in less than half of his group, some agreement on important traits in 1/3 of the cases, and complete disagreement in 1/5. While the test is uncertain for the psychological study of children, he concludes, it is highly valuable in connection with other psychiatric and pedagogic devices.

Schneider (**123**) and Galant (**38**) use case studies to show the test's value in detecting mental and moral defects. Schneider makes special study of 21 subjects selected because of conflicting scores on several intelligence tests and the Rorschach test. Psychograms studied show much fantasy living, tendencies to depressiveness and neuroticism, egocentric affectivity, many schizophrenic tendencies and especially many inhibitions. No control group is used, however. For him, the Rorschach proves to be of valuable service in detecting the inhibited individuals.

Beck (**7**) finds the test unusually valuable since it can probe the emotional life of the individual without in itself exciting an emotion other than the pattern characteristic for that individual. He presents (**5**) psychograms of a feeble-minded girl, a person of superior intelligence, a behavior problem case, and a paranoid schizophrenic patient, studying them in conjunction with their respective case histories. Again (**8**), studying 37 problem children, he analyzes specifically the dilated and constricted Rorschach patterns by comparing them with other clinical data, claiming to confirm Rorschach's pictures of these types. Three diagnoses, however, are not substantiated by the clinical findings.

The Rorschach psychograms of 75 criminals described as "antisocial" or "moral defectives" are studied by Boss (**16**) who reports that the results resemble the Rorschach norms for certain mental

disorders. Boss concludes the test is useful in making character studies of anti-social psychopaths. Willemse (149) includes the ink-blot test in his study of constitutional types in delinquency, applying it especially for analysis of temperament and its effect on crime. No results are given in this connection, however.

Interesting case studies based on the Rorschach patterns are reported by Müller (93) for a criminal, and by Baenziger (4) for a religious fanatic. Furrer analyzes one of Loosli-Usteri's problem children (75). Prados and Linares (106) investigate the personality of a paranoid schizophrenic patient. Salas (120, 121) includes several case studies in his articles. Dubitscher (26) compares his Rorschach diagnoses with independent case studies, reporting most of them in agreement, but, like Löpfe and Beck, admits disagreements also. Skalweit (126), Kerr (54), and Zulliger (152) likewise present case studies showing the diagnostic value of the test. Its value in forensic examination is observed by Fränkel and Benjamin (34) who present several case studies showing the test useful in differentiating individuals who are defective mentally and those pretending ignorance. Evaluation of the results, however, require care and thorough experience.

A Russian study is reported by Hackebush (44) of a subject 34 years old in which the Rorschach test is used in conjunction with other tests to illustrate Pavlov's hypothesis that hypnosis is an internal inhibition. Reference has been made to Wertham and Bleuler (147) who use the test twice, before and after administering the drug mascaline, to show the inconstancy in the formal character of the personality.

Some investigators, failing to validate Rorschach factors objectively, give their subjective impressions. Beck (6, 7) feels that the color factor and the space detail tend to reveal the traits Rorschach suggested. Subjectively, Vernon (137) observes that the scores for pedantic and depressive tendencies do show up in his groups, although he cannot validate them against any objective measurements. He does not feel that the Do, DS and C bear out Rorschach's contentions for these factors. Oeser (100) and Mira (89) estimate some significance for the C and Color Shock factors. Mira (89) attains color shock in 14% of his subjects. Hertz (46) reports practically no evidences of color shock in her 300 normal cases. Wells (145) reports that from his experience with cases his results have been "seldom open to error on the side of flattery, save perhaps in respect to intelligence; but they have

shown striking agreement with what under these conditions are given as the subject's characteristics by himself and others".

Several studies indicate that the test can reveal the content of the mind. Beck (7) shows that the test provides the cue to the actual content of the subject's mind and claims that clinicians can get a real cross-section of the subject's entire personality. Löpfe (79) concludes that the test is especially valuable in uncovering latent mental traits in children. Oberholzer (119) testifies to the value of the technique as a supplementary aid to psychoanalysis. Furrer (36) in like manner reports the test valuable in psychoanalytic therapy. Other investigators, as Christoffel (21), Glover (42), Mira (89), Pfänder (103), Salas (120), and Roemer (111), discuss the method in connection with psychoanalysis. Both Roemer and Mira find the test invaluable in uncovering latent pathological complexes and for discovering fitness for life choices. Matzkevitch (86) also discovers hidden pathological complexes in his group of psychoneurotics, using the Rorschach technique and claiming to corroborate his data by the Jung Association Test.

(3) *Correlational technique.* Vernon (137) attempts to validate Rorschach factors indicative of pedantic and depressive tendencies against objective criteria, such as Association Tests, psychogalvanic reflex, Woodworth Personal Data Sheet and Willoughby Emotional Maturity Scale, but with little success. He thinks that the tests and the Rorschach scores may cover different aspects of the same general traits and hence show no correspondence. Vernon comments that the validity of the factors can really never be established by correlation technique. He places more hope in the method of making statistically reliable comparisons between groups selected by experts for a specific trait or group of traits and analyzing Rorschach factors in conjunction with other personality criteria.

Hertz (46) reports results with this technique which are more encouraging. Taking the Woodworth-Mathews Total Score as the criterion of degree of neurotic involvement, emotional stability and adaptability, she obtains suggestive relationships with CF, C, F, M, Dr, %O and P factors. Correlating certain discriminative scores on the basis of regrouping of items on the Woodworth questionnaire, DS appears to suggest lack of adjustment, CF emotional instability, and a high percentage of O peculiar ideas, superstitions and the like.

(E) *Summary: Validation of Non-Intellectual Factors.* 1. Comparisons of the Rorschach *Erlebnistypen* with other typological systems, though extensive and elaborate, give few positive findings.

a. No correspondence is observed between the movement and color scores and measures of introversion-extraversion based on the Neymann-Kohlstedt questionnaire (Vernon), but a satisfactory relationship between Rorschach's introversive-extratensive types and Allport's submissive and ascendant types is reported (Hertz).

b. Characteristically differing psychograms are reported for manic and depressive subjects, validating in part claims for color and movement (Levy and Beck, Enke).

c. Kretschmer's pyknic type shows some correspondence with the extratensive type, the schizaffin with the introversive (Munz, Enke, Mohr and Gundlach).

d. Form and color types correspond in some measure to Rorschach form and color factors (Poppinga, Oeser) but very little to introversive and extratensive types.

e. Eidetic types may be distinguished in some measure by certain Rorschach factors (Weil, O. Mueller, Schenck, Bryn).

f. Some evidence points to a definite relationship between graphological types and the Rorschach introversive types (Halvorsen).

g. Since most investigations using typologies fail to include statistical procedures and scientific controls, conclusions in respect to the Rorschach types must be looked upon with caution.

2. Innumerable investigators testify to the efficacy of the test as a clinical diagnostic instrument, as Rorschach claimed.

a. In comparing groups of known personality, characteristic differences have been established in terms of Rorschach factors and combinations of factors.

(1) Asylum and clinic children have been identified (Loosli-Usteri), mental defectives (Pfister, Beck, Hertz, Kerr), stable and unstable groups (Hertz), ascendant and submissive groups (Hertz), socially adapted mental defectives and maladjusted groups (Pfister, Beck), normal, and neurotic and psychopathic groups (Binder, Hertz, Dubitscher, Salas).

(2) The various mental disorders have been diagnosed by the Rorschach instrument: schizophrenia, manic-depressive psychosis (Enke, Kretschmer), post-encephalitic Parkinsonism (Veit), and epilepsy (Eyrich).

(3) To the extent that certain Rorschach factors can differentiate these groups, to that extent their diagnostic significance has been substantiated.

b. Validation has been to a great extent in terms of comparisons between Rorschach diagnoses and case studies and general qualitative impressions.

(1) Reports of this nature show the test valuable in diagnosing mental and moral defects, inhibitions, neuroticism, excessive fantasy living, maladjustment, delinquent tendencies, psychopathic tendencies, perverseness, negativism, feelings of inferiority, mental conflict, malingering, hidden pathological complexes, etc.

(2) Many investigators consider the test sufficiently validated because correspondence with case studies has been demonstrated. Generalizations on this subjective basis, however, are interesting but not psychologically valid. Such results are provocative and await more objective validation.

c. The few studies using correlational technique have not been very profitable. Suggestive relationships are observed between emotional stability, adaptability, neurotic tendencies, and Rorschach factors (Hertz).

VI. Conclusion: The Current Status of the Rorschach Ink-Blot Test

A cursory review of the literature in this field suggests that while the Rorschach test has challenged the specialist engaged in the field of personality, it has not as yet gained renown comparable to that won by other psychological tests. Extensive use of the test in its present form has been seriously retarded. Several reasons suggest themselves.

1. No guide or manual to give the necessary information as to its use has been produced. The original manual of Rorschach is not adequate to give the student a satisfactory comprehension of the technique and the proper evaluation of the test factors.

2. The test was originally developed chiefly with psychiatric material and with a limited number of cases. To date, comparatively few systematic and statistical studies have been made with representative normal groups.

3. Material which is available provides data which are not comparable owing to the diversity of techniques used.

4. Standards for groups in the United States are not yet available and norms used in Europe are admittedly inadequate.

5. The technique presents inherent difficulties and obstacles, for the interpretation of the data requires special aptitude for and training in the methods of diagnosis of personality, making a fine critical sense and much insight imperative prerequisites.

6. The scoring, especially, is still subjective, defying complete objectivity.

7. With one exception, the reliability of the test has not been established.

8. Few of Rorschach's claims for his diagnostic categories have been substantiated statistically, while many lack any kind of confirmation.

Despite these limitations, however, the Rorschach test merits extended study for many reasons.

1. Rorschach's early work gave interesting results despite the limited number of cases and lack of adequate standardization.

2. Subsequent study has furnished data highly provocative, justifying further experimentation.

3. The test is another form of the free association technique which has been found useful in the past for describing personality.

4. The test is viewed as a new and promising approach to the study of personality, combining as it does statistical measurements with qualitative description.

5. If the test can be proved reliable and valid as an instrument for intelligence testing, it will be a new and different approach, simple, objective, applicable to all groups, and free from outside influences. The use of the test in conjunction with a standardized intelligence test might be of service.

6. The test, if reliable, would be invaluable in studying the affective aspects of the personality, not only in revealing special traits but also in illuminating the entire background against which they must be seen to be evaluated.

7. Intelligence tests are criticized because they take little account of the concomitant emotional state of the subject. "Personality tests" are criticized in that they really probe intelligence rather than the affective life of the individual. The Rorschach test, if reliable, would be unique in that it would at the same time reveal general intelligence level and expose the emotional traits, thus avoiding the errors ascribed to most "personality tests".

8. The test offers an additional technique in the field of individual psychology since it reveals trains of thought, perseveration of ideas, and stereotyped ways of thinking, and since it can reflect interests, education, training, specialization, and general cultural background.

9. The test has been shown to be a good instrument for differentiating groups.

10. Various investigators who have applied the test practically claim that it "works". Differential personality patterns are

revealed in normal individuals and diagnoses of the different mental disorders are said to be possible.

The Rorschach test is still at the beginning of its history. Much remains to be done before it can be accepted in full. That it has a future, however, cannot be denied.

BIBLIOGRAPHY

The bibliography listed below includes all references which have come to the writer's notice up to January, 1934.

1. ALLPORT, G. W., Eidetic Imagery. *Brit. J. Psychol.*, 1925, **15**, 99–120.
2. ALLPORT, G. W., The Study of the Undivided Personality. *J. Abn. Psychol.*, 1924, **19**, 132–141.
3. ALLPORT, G. W., and VERNON, P. E., The Field of Personality. *Psychol. Bull.*, 1930, **27**, 677–730.
4. BAENZIGER, H., Die Frage der Schizophrenie bei einem Mitglied der Sekte Anton Unternährers. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1927, **110**, 627–694.
5. BECK, S. J., Personality Diagnosis by Means of the Rorschach Test. *Amer. J. Orthopsychiat.*, 1930, **1**, 81–88.
6. BECK, S. J., The Rorschach Test and Personality Diagnosis. I. Feeble-minded. *Amer. J. Psychiat.*, 1930, **10**, 19–52. Also in *Institute for Child Guidance Studies* (L. G. Lowrey), 222–261. New York: Commonwealth Fund, 1931.
7. BECK, S. J., The Rorschach Test as Applied to a Feeble-minded Group. *Arch. of Psychol.*, No. 136, 1932. Pp. 84.
8. BECK, S. J., The Rorschach Test in Problem Children. *Amer. J. Orthopsychiat.*, 1931, 1, 501–509.
9. BECK, S. J., Configurational Tendencies in Rorschach Responses. *Psychol. Bull.*, 1932, **29**, 632; *Amer. J. Psychol.*, 1933, **45**, 433–443.
10. BEHN-ESCHENBURG, H., *Psychische Schüleruntersuchungen mit dem Formdeutversuch.* Ernst Bircher Verlag, Bern u. Leipzig, 1931, pp. 69. Also Huber, Bern.
11. BENDER, I. E., Ascendance-Submission in Relation to Certain Other Factors in Personality. *J. Abn. & Soc. Psychol.*, 1928, **23**, 137–143.
12. BINDER, H., Die Helldunkeldeutungen im psychodiagnostischen Experiment von Rorschach. *Schweiz. Arch. Neur.*, 1932–1933, **30**, 1–67, 233–286. Republished in monograph form by Orell Füssli, Zürich, 1932. Pp. 123.
13. BINSWANGER, L., Bemerkungen zu Hermann Rorschach's Psychodiagnostik. *Internat. Zsch. f. Psychoanal.*, 1923, **9**, 512–523.
14. BLEULER, M., Der Rorschachsche Formdeutversuch bei Geschwistern. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1929, **118**, 366–398.
15. BLEULER, M., The Shaping of Personality by Environment and Heredity. *Character and Personality*, 1933, **1**, 286–300.
16. BOSS, M., Psychologisch-charakterlogische Untersuchungen bei antisozialen Psychopathen mit Hilfe des Rorschachschen Formdeutversuches. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1931, **133**, 544–575.

17. BRYN, D., Human Types with an Experimental Contribution to the Diagnostic Study of Personality Typology. In Norwegian. Unpublished M.A. Thesis, Oslo: Frederickiana University, 1932.
18. BUMKE, O., *Handbuch der Geisteskrankheiten.* Berlin: Springer, 1928–1932.
19. CANTRIL, H., and ALLPORT, G. W., Recent Applications of "The Study of Values". *J. Abn. & Soc. Psychol.*, 1933, **28**, 259–273.
20. CARL, H., Versuch über tachistoskopisches Bilderkennen. *Zsch. f. Psychol.*, 1933, **129**, 1–42.
21. CHRISTOFFEL, H., Die gegenwartige praktische Bedeutung der Psychoanalyse für die Medizin und speziell für die Psychiatrie. *Schweiz. med. Woch.*, 1924, **54**, 449–455.
22. CRANE, H. W., The Limitations of Psychometrics in Clinical Practise. *J. Abn. & Soc. Psychol.*, 1931, **26**, 199.
23. DAMBACH, K., Die Mehrfachbarkeit und ihre typologische Bedeutung. *Zsch. f. Psychol.*, 1929, Erg. Bd. 14, 159–236.
24. DÉRIAZ, W., Profil psychologique des redresseurs de barres. *Arch. de Psychol.*, 1932, **23**, 230–238.
25. DILTHEY, W., Ideen über eine beschreibende und zergliedernde Psychologie. *Sitzungsberichte der königl. preuss. Akad. der Wiss.*, zu Berlin, 1894, **11**.
26. DUBITSCHER, F., Der Rorschachsche Formdeutversuch als diagnostisches Hilfsmittel. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1932, **138**, 515–535.
27. DUBITSCHER, F., Der Rorschachsche Formdeutversuch bei erwachsenen Psychopathischen und schwachsinnigen Kindern. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1932, **142**, 129–158.
28. ENKE, W., Die Konstitutionstypen im Rorschachschen Experiment. *Zsch. f. d. Neur. u. Psychiat.*, 1927, **108**, 645–674.
29. ENKE, W., Die Bedeutung des Rorschachschen Formdeutversuches für die Psychotherapie. *Sitzungsber. d. Ges. z. Beförderg. d. ges. Naturw. z. Marburg*, 1927, LXII, 621–633. Berlin: O. Elsner Verlag.
30. ENKE, W., Experimentalpsychologische Studien zur Konstitutionsforschung. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1928, **114**, 770–794.
31. EWALD, G., *Temperament und Charakter.* Berlin: Springer, 1924. Pp. 156.
32. EYRICH, M., Über Charakter und Charakterveränderung bei kindlichen und jugendlichen Epileptikern. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1932, **141**, 640–644.
33. FLUGEL, J. C., Review and Abstract of No. 62. *Int. Zsch. f. Psychoanal.*, 1922, **8**, 362–365.
34. FRÄNKEL, F., und BENJAMIN, D., Der Rorschachsche Formdeutversuch als differential-diagnostisches Mittel für Gutachter. *Aerzt. sachv. Ztg.*, 1932, **38**, 20–23.
35. FUCHS, P., Experimentelle Untersuchungen zum Problem der Auffassung. I. Teil. Über die Auffassung sinnloser Figuren. *Arch. f. d. ges. Psychol.*, 1929, **73**, 257–368.
36. FURRER, H., Über der Bedeutung der "B" in Rorschachschen Versuch. *Imago*, 1925, **11**, 362–365.
37. FURRER, H., *Der Auffassungsvorgang beim Rorschachschen psychodiagnostischen Versuch.* Zürich, 1930.

38. GALANT, S., Praktische Intelligenz und Moralische Imbezillität. *Arch. f. Psychiat. u. Nervenkr.*, 1922, **64**, 339–382.
39. GANZ, E., *Le test de Rorschach appliqué à 43 garçons anormaux de 10–14 ans.* Unpublished Thesis, Institute J. J. Rousseau, 1931.
40. GIESE, F., Psychoanalytische Psychotechnik. *Imago*, 1924, **10**, 93–152.
41. GIESE, F., *Handbuch psychotechnischer Eigenprüfungen.* Halle: Carl Marhold Verlagsbuchhandlung, 1925. Pp. 870.
42. GLOVER, E., Einige Probleme der Psychoanalytischen Charakterologie. *Internat. Zsch. f. Psychoanal.*, 1926, **12**, 326–333.
43. GORDON, R. G., and NORMAN, R. M., Some Psychological Experiments on Mental Defectives in Relation to the Perceptual Configurations which May Underlie Speech. Part II. *Brit. J. Psychol.*, 1932, **23**, 85–113.
44. HACKEBUSH, V., BLINKOVSKI, and FUNDYLER, R., An Attempt at a Study of the Development of Personality with the Aid of Hypnosis. In Russian. *Trudy psichonevr. Inst. Kiev*, 1930, **11**, 236–272. *Psychol. Abstr.*, 1933, **7**, 5800.
45. HALVORSEN, H., Eine Korrelation zwischen Rorschach Test und Graphologie. *Zsch. f. angew. Psychol.*, 1931, **40**, 34–39.
46. HERTZ, M. R., *The Rorschach Ink-blot Test.* Unpublished Thesis, Western Reserve University Library, Cleveland, Ohio. 1932
47. HERTZ, M. R., The Reliability of the Rorschach Ink-blot Test. *J. Appl. Psychol.*, 1934, **18**, 461–477.
48. JAENSCH, E. R., *Eidetic Imagery.* Kegan Paul, 1930.
49. JAENSCH, E. R., *Grundformen menschlichen Seins.* Berlin: Elsner, 1930.
50. JAENSCH, E. R., Studien zur Psychologie Menschlicher Typen II. WEIL, H., Wahrnesmungsversuche an Integrierten und Nichtintegrierten. *Zsch. Psychol.*, 1929, **3**, 1–50.
51. JUARROS, C., et SORIANO, M., Le Psychodiagnostic de Rorschach chez les enfants anormaux. *Conf. Internat. de Psychotechnique de Paris*, 1927, pp. 595–605. Also in Spanish, *Siglo. méd.*, 1927, **80**, 413–417.
52. JUARROS, C., et SORIANO, M., Comparative Results of Normal and Abnormal Children on the Rorschach Test. *Arch. españ. Pediatr.*, 1929, **13**, 609–613.
53. JUNG, C., *Psychological Types.* New York: Harcourt, Brace and Co., 1925.
54. KERR, M., *The Rorschach Test Applied to Children.* Paper read to the Brit. Psychol. Soc., Nov., 1933. Not yet published.
55. KLÜVER, H., An Analysis of Recent Work on the Problem of Types. *J. Nerv. and Ment. Dis.*, 1925, **62**, 561–596.
56. KLÜVER, H., Contemporary German Psychology. Supplement in *An Historical Introduction to Modern Psychology* by Gardner Murphy.
57. KLÜVER, H., An Experimental Study of the Eidetic Type. *Gen. Psychol. Monog.*, 1926, **1**, No. 2.
58. KLÜVER, H., Fragmentary Eidetic Imagery. *Psychol. Rev.*, 1930, **37**, 441.
59. KLÜVER, H., The Problem of Type in "Cultural Science Psychology". *J. Philos.*, 1925, **22**, 225–234.
60. KLÜVER, H., Psychological and Sociological Types. *Psychol. Rev.*, 1924, **31**, 446–462.

61. KOEHN, W., Psychologische Untersuchungen an Zwillingen und Geschwistern über die Vererbung der Kombinationsfähigkeit der Intelligenz und der Phantasie. *Arch. f. d. ges. Psychol.*, 1933, **88**, 131–200.
62. KOHS, C. H., The Association Method in Its Relation to the Complex and Complex Indicators. *Amer. J. Psychol.*, 1914, **25**, 544–594.
63. KOHT, A. G., Étude d'un test d'imagination sur des écoliers parisiens. *L'ann. psychol.*, 1930, **30**, 40–72. Abstr. in *Zsch. ges. Neur. u. Psychiat.*, 1931, **60**, 652–653.
64. KRETSCHMER, E., Discussion of No. 72. *Zentbl. f. d. ges. Neur. u. Psychiat.*, 1927, **45**, 840.
65. KRETSCHMER, E., *Physique and Character.* New York: Harcourt, Brace and Co., 1921.
66. KRETSCHMER, E., *Medizinische Psychologie.* Leipzig: Thieme, 1926.
67. KRONFELD, A., *Lehrbuch der Charakter.* Berlin: Springer, 1932. Pp. 451.
68. KRUEGER, F., *Über Entwicklungspsychologie,* 1915.
69. KÜLPE, O., Versuche über Abstraktion. *Bericht u. d. I Kongress f. exper. Psychol.*, 1904.
70. LANGE, J., und KRAEPELIN, E., *Allgemeine Psychiatrie.* Leipzig: Barth, 1927.
71. LEINWEBER, B., *Empirisch-psychologische Beiträge zur Typologie des dichterischen Schaffens.* Langensalza: Beyer, 1929. Pp. 96.
72. LEVY, D., and BECK, S. J., *The Rorschach Test in Manic-Depressive Psychosis.* XI, Research Publications of the Assoc. for Research in Nervous and Mental Diseases. Baltimore: Williams and Wilkins, 1931, 167–181.
73. LINARES, A., Diagnosis of Abnormal and Superior Children. *Rev. de ped.*, 1931, **10**, 412–417, 456–464.
74. LINARES, A., Experiments on Normal Spanish Children with the Rorschach Test. *Arch. neurobiol.*, 1932, **12**, 693–738.
75. LOOSLI-USTERI, M., Le test de Rorschach appliqué à différents groupes d'enfants de 10–13 ans. *Arch. de Psychol.*, 1929, **85**, 51–106.
76. LOOSLI-USTERI, M., Von der Geister- und Seelenverfassung der Anstaltskinder. *Psychol. Rundschau,* 1930, **2**, 45–49. *Psychol. Abstr.*, 1931, 4019.
77. LOOSLI-USTERI, M., Les Interprétations dans le test de Rorschach. Interprétations kinesthesiques et interprétations-couleur. *Arch. de Psychol.*, 1932, **23**, 349–365. *Psychol. Abstr.*, 1933, 4191.
78. LOOSLI-USTERI, M., Le conscience du hasard chez l'enfant. *Arch. de Psychol.*, 1931, **23**, 45–66.
79. LÖPFE, A., Über Rorschachsche Formdeutversuche mit 10–13 jährigen Knaben. *Zsch. f. angew. Psychol.*, 1925, **26**, 202–253.
80. LOWREY, L. G., The Study of Personality. *Amer. J. Psychiat.*, 1929, **8**, 695–703.
81. LOWREY, L. G., A contribution to the *Proceedings of the Second Colloquium on Personality Investigation.* Baltimore: Johns Hopkins Univ. Press, 1930. Pp. 205.
82. LUITHLEN, W. P., Zur Psychologie der Initiative und der Führereigenschafen. *Zsch. f. angew. Psychol.*, 1931, **39**, 56–122.

83. MALLER, J. B., Studies in Character and Personality in German Psychological Literature. *Psychol. Bull.*, 1933, **30**, 209–232.
84. MATEER, F., The Future of Clinical Psychology. *J. Delinq.*, 1911, **6**, 283–291.
85. MATEER, F., *The Unstable Child.* New York: D. Appleton and Co., 1924. Pp. 471.
86. MATZKEVITCH, A. N., Kmetodike otiskani ja skritogo pathologischeskogo komplexa po metodu Rorschacha. *Truid ukr. psikhonevr. instit.*, 1931, **15**, 44–51. *Psychol. Abstr.*, 1933, 1641.
87. MEGGENDORFER, F., Klinische und geneologische Untersuchungen über "Moral Insanity". *Zsch. f. d. Neur. u. Psychiat.*, 1921, **66**, 208–231.
88. MELTZER, H., Personality Differences between Stuttering and Non-stuttering Children as Indicated by the Rorschach Test. *Psychol. Bull.*, 1933, **30**, 726–727.
89. MIRA, L. E., Sobre et valor del Psicodiagnostico de Rorschach. *Progressos de la Clinica*, 1925, 808–845.
90. MIRA, L. E., Exploración de la afectividad. *Revista Médica de Barcelona*, 1930, **14**, 222–259.
91. MOHR, G. J., and GUNDLACH, R. H., Relation Between Physique and Performance. *J. Exper. Psychol.*, 1927, **10**, 117–157.
92. MORGAN, J. J. B., *The Psychology of Abnormal People.* New York: Longmans, Green, 1928. Pp. 627.
93. MÜLLER, M., Zur Psychologie eines Mordversuches. *Schweiz. Zsch. f. Strafrecht*, 1925, **38**, 153–178.
94. MÜLLER, M., Der Rorschachsche Formdeutversuch, seine Schwierigkeiten und Ergebnisse. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1929, **118**, 598–620.
95. MUELLER, O., Beiträge zur Lehre menschlicher Typen nach der Methode unvollständiger Reizdarbietung. *Zsch. f. Psychol.*, 1929, **111**, 51–145.
96. MUNZ, E., Die Reaktion des Pyknickes im Rorschachschen psychodiagnostischen Versuch. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1924, **91**, 26–92.
97. NEYMANN, C. A., and KOHLSTEDT, K. D., A New Diagnostic Test for Introversion-Extroversion. *J. Abn. and Soc. Psychol.*, 1929, **23**, 482–487.
98. OBERHOLZER, E., Zur Auswertung des Rorschachen Versuchs bezgl. Diagnose und Krankheits resp. Heilungsablauf. *Schweiz. Arch. Neur.*, 1929, **24**.
99. OBERHOLZER, E., Zur Differentialdiagnose psychischer Folgezustände nach Schädeltraumen mittels des Rorschachschen Formdeutversuchs. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1932, **61**, 507.
100. OESER, O. A., Some Experiments on the Abstraction of Form and Color. Pt. II. Rorschach Test. *Brit. J. Psychol.*, 1932, **22**, 287–323.
101. OESER, O. A., Typological Methods in Experimental Psychology. *Psyche*, 1930, **10**, 80–89.
102. PFAHLER, G., System der Typenlehren. Grundlegung einer pädagogischen Typenlehre. *Zsch. f. Psychol.*, 1929, Erg. Bd. 15, pp. 334.
103. PFÄNDER, A., Grundprobleme der Charakterologie. *Jahrb. f. Charakterol.*, 1924, **1**.
104. PFISTER, O., Ergebnisse des Rorschachschen Versuches bei Oligophrenen. *Allg. Zsch. f. Psychiat.*, 1925, **87**, 198–223.

105. Poppinga, O., Die teilinhaltliche Beachtung von Form und Farbe bei Erwachsenen in ihrer Beziehung zur strukturpsychologischen Typenlehre. *Zsch. f. Psychol.*, 1931, **121**, 137–177.

106. Prados y Such, M., and Linares, Maza, A., A Contribution to the Study of the Paranoid State. (In Spanish.) *Arch. neurobiol.*, 1932, **12**, 54–86.

107. Reymert, M. L., Qualitative Factors in Mental Measurements. *Arkiv. for psykolgi och pedagogik*, 1928, 27–38.

108. Reymert, M. L., and Hartman, M. L., A Qualitative and Quantitative Analysis of a Mental Test. *Amer. J. Psychol.*, 1933, **45**, 87–105.

109. Roback, A. A., *A Bibliography of Character and Personality.* Cambridge, Mass.: Sci-Art Publishers, 1927. Pp. 340.

110. Roback, A. A., *The Psychology of Character.* New York: Harcourt, 1927. Pp. 595.

111. Roemer, G. A., Die Innenwelt einer Persönlichkeit und das Problem ihrer wissenschaftlichen Erschliessung. *Psychol. Rundschau*, 1930, **2**, 4–12. *Psychol. Abstr.*, 1931, 2973. *Psychol. Rundschau*, 1930, **2**, 33–41. *Psychol. Abstr.*, 1931, 3907. *Psychol. Rundschau*, 1930, **2**, 69–76, 101–109. Reprint: *Die wissenschaftliche Erschliessung der Innenwalt einer Persönlichkeit.* Basle: Birkhäuser, 1931. Pp. 42.

112. Roemer, G. A., Psychographische Tiefenanalyse einer Grossindustriellen und seiner Stabes. *Prakt. Psychol.*, 1922–1923, **4**, 16–28.

113. Roemer, G. A., Psychographische Tiefenanalyse und innerer Aufbau der Persönlichkeit. *Kong. f. exper. Psychol., Leipzig*, 1923, **9**, 190–193.

114. Roemer, G. A., Tiefentest und innerer Aufbau der Persönlichkeit. *Kong. f. exper. Psychol.*, **8**. Fischer, Jena, 1923.

115. Roemer, G. A., Über die Anwendung des psychodiagnostischen Verfahrens nach Rorschach auf Fragen der Berufsberatung. *Kong. f. exper. Psychol.*, Marburg, 1921, **7**, 165–167.

116. Roemer, G. A., Über die Auffindung des aktuellen Kernproblems einer Persönlichkeit durch die Tiefentestmethode. *Zsch. f. Menschenk.*, 1926, **1**, 48–55.

117. Rorschach, H., *Psychodiagnostik. Methodik und Ergebnisse eines Wahrnehmungsdiagnostischen Experiments.* Bern: Bircher, 1921. Pp. 42.

118. Rorschach, H., *Psychodiagnostik.* Bern: Huber, 1932. Enlarged to include 117 and 119. Pp. 227.

119. Rorschach, H., und Oberholzer, E., Zur Auswertung des Formdeutversuche für die Psychoanalyse. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1923, **82**, 240–273. The same, translated: The Application of the Interpretation of Form to Psychoanalysis. *J. Nerv. and Ment. Dis.*, 1924, **60**, 225–248, 359–379.

120. Salas, J., El psicodiagnostico de Rorschach. *Arch. neurobiol.*, 1932, **12**, 316–339. *Psychol. Abstr.*, 1933, 1182.

121. Salas, J., La classificación de las repuestas en el psicodiagnostico de Rorschach. *Arch. neurobiol.*, 1933, **8**, 45–80. *Psychol. Abstr.*, 1933, 5567.

122. Schenck, H., Experimentell-strukturpsychologische Untersuchungen über den "dynamischen Typus". *Zsch. f. Psychol.*, 1929, **113**, 91–208.

123. SCHNEIDER, E., Die Bedeutung des Rorschachschen Formdeutversuches zur Ermittlung intellektuel gehemmter Schüler. *Zsch. f. angew. Psychol.*, 1929, **32**, 102–163.

124. SCHWEGLER, R., A Study in Introvert-Extravert Responses to Certain Test Situations. *T. C. Contr. Educ.*, 1929, 361.

125. SHUEY, H., A New Interpretation of the Rorschach Test. *Psychol. Rev.*, 1933, **40**, 213–215.

126. SKALWEIT, (ROSTOCK-GEHLSHEIM), Praktisch-diagnostische Verwertung des Rorschachschen Formdeutversuches. *Vers. Norddtsch. Psychiater. u. Neurol.*, Kiel, 1931, **10**, Sitzg., 24–25. Abstract: *Zentbl. f. d. ges. Neur. u. Psychiat.*, 1932, **63**, 21.

127. SOUKUP, F., The Study of Personality and Rorschach's Test. In Czech. *Čās. lék. česk.*, 1931, **1**, 881–887. Abstract: *Zentbl. f. d. ges. Neur.*, 1932, **61**, 564.

128. SPRANGER, E., *Types of Men.* Halle: Niemeyer, 1928.

129. STEIN, ERICH, New Ways of Investigating the Problem of Personality. *Psyche*, 1923, **3**, 358–366.

130. STRUVE, K., Typische Ablaufsformen des Deutens bei 14—bis 15—jährigen Schulkindern. *Zsch. f. angew. Psychol.*, 1930, **37**, 204–274.

131. STUMBERG, D., A Study of Poetic Talent. *J. Exper. Psychol.*, 1928, **11**, 219–234.

132. SYMONDS, P. M., *Diagnosing Personality and Conduct.* New York: The Century Co., 1931. Pp. 602.

133. VEIT, H., Der Parkinsonismus nach Encephalitis epidemica im Rorschachschen Formdeutversuch. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1927, **110**, 301–324.

134. VEIT, H., Der Rorschachsche Versuch als klinisches Hilfsmittel. XLIV. *Jahresversammlung der Sudwestdtsch. Psychiater*, Freiburg, 1926. Abstract: *Zentbl. f. d. ges. Neur. u. Psychiat.*, 1927, **45**, 840.

135. VERNON, P. E., The Rorschach Ink-blot Test. *Brit. J. Med. Psychol.*, 1933, **13**, 89–114.

136. VERNON, P. E., The Rorschach Ink-blot Test. *Ibid.*, 179–200.

137. VERNON, P. E., The Rorschach Ink-blot Test. *Ibid.*, 271–291.

138. VERNON, P. E., and ALLPORT, G. W., A Test for Personal Values. *J. Abn. and Soc. Psychol.*, 1932, **25**, 231–248.

139. VERSCHUER, O. V., Erbpsychologische Untersuchungen an Zwillingen. *Zsch. f. induktive Abstammungs- u. Vererbungslehre*, 1930, **54**, 280–285.

140. VERSCHUER, O. V., *Vererbung und Erziehung.* Berlin: G. Just, 1930.

141. WATSON, G., Measures of Character and Personality. *Psychol. Bull.*, 1932, **29**, 147–176.

142. WEBER, A., Abstract of No. 63. *Int. Zsch. f. Psychoanal.*, 1924, **10**, 311–312.

143. WEIL, H., Wahrnehmungsversuche an Integrierten und Nichtintegrierten. *Zsch. f. Psychol.*, 1929, **111**, 1–50.

144. WELLS, F. L., *Personality Traits.* Appendix D. Report of the Conference on Individual Differences in the Character and Rate of Psychological Development. Washington: National Research Council, 1931.

145. WELLS, F. L., *The Systematic Description of Personality.* Conference on Individual Differences. *Ibid.*, 1931.
146. WERTHAM, F., Progress in Psychiatry. IV. Experimental Type Psychology. *Arch. Neur. u. Psychiat.*, 1930, **24**, 605–611.
147. WERTHAM, F., and BLEULER, M., Inconstancy of the Formal Structure of the Personality: Experimental Study of the Influence of Mescaline on the Rorschach Test. *Arch. Neur. u. Psychiat.*, 1932, **28**, 52–70.
148. WHIPPLE, G. M., *Manual of Mental and Physical Tests. Complex Processes.* Baltimore: Warwick, 1924. Pp. 336.
149. WILLEMSE, W. A., *Constitutional Types in Delinquency.* London: Kegan Paul. Pp. 266.
150. YOUNG, K., The History of Mental Testing. *Ped. Sem.*, 1923, **31**, 1–48.
151. ZIEHEN, T., Die Prufung der Phantasietätigkeiten bei Kranken und Gesunden. *J. Psychol. u. Neur.*, 1928, **37**, 422–427.
152. ZULLIGER, H., Der Rorschachsche Testversuch im Dienste der Erziehungsberatung. *Zsch. f. Psychanal. Päd.*, 1932, **6**, 489–495.

DIFFERENTIAL ERRORS IN ANIMAL MAZES[1]

BY JACK BUEL
University of California

The determination of the causal factors underlying differential maze errors (the distribution of errors in the various blinds of the maze) has long been an unsatisfactorily analyzed problem. This problem was, however, one of the first to be investigated in animal mazes. The results of early experiments were, for the most part, vitiated by the fact that the maze forms used were of such a nature that uncontrolled variables were included. Even today, with the accumulated knowledge of well-founded principles of maze construction, there is an almost insurmountable difficulty in constructing a maze that will control even the simplest of irrelevant variables. An example, which, on the surface at least, seems to control the effect of structural features of the maze, is Warden's symmetrical linear maze (94). This maze, made up of standard Warner-Warden units, is so constructed as to present spatially identical and symmetrical sequences of patterns. Spence (70) and the present writer (7) have recently shown, however, that even here, asymmetrical results are obtained because *psychologically* asymmetrical features are still present.

The shape and type of structural unit of the maze constitutes *only one* set of variables. With finer and finer analysis more factors are found to be potently involved in the magnitude and distribution of errors, but no systematic attempt has been made to utilize this complexity and to recognize clearly the difficulties it presents.

The present paper will attempt to suggest what some of the factors determining differential errors may be, to indicate some of the relationships existing among them, and to examine the consequences of such findings for theoretical psychology.

A full list of factors which have been found to influence differential errors would make it necessary to quote practically all the

[1] The writer is indebted to Professors Warner Brown, E. C. Tolman, and R. C. Tryon for many helpful suggestions and criticisms in the preparation of this paper.

experiments on mazes. We cannot give all this related evidence here, but we shall give enough to support our argument. The list here makes no pretense to completeness, nor does it include all the most significantly related experiments. It will be enough for our purposes if we can show the very great *number* and *complexity* of the factors involved.

The following factors are classed under arbitrary headings, and are not to be thought of as rigorous groups, but rather as convenient broad classes *which are not mutually exclusive,* but which, on the contrary, are *highly interrelated.* We shall attempt to indicate some of these relationships in the following lists. Many interrelationships we have failed to indicate may be obvious to the reader. We cannot indicate more than a few of these relationships in this paper.

We shall begin with those factors which relate to the inherent organization of the animal.

I. The Genetic Make-up of the Organism

The general behavior propensities of the species to which the organism belongs may well be causal in producing differential errors. The circular behavior of some species when released into an open space (Peckham, Cornetz, Santschi) would tend to cause differential errors, since blinds and paths allowing behavior consistent with this tendency would be entered more frequently than those inconsistent with this tendency.

Husband (**41**) comparing humans and rats in maze learning, finds that " entirely different types of errors were made by the two groups: humans tend to alternate, rats to maintain a direction. . . . Humans learn the outside portions of the maze first; rats learn in a regressive order ". The rats were also found to be less variable.

Vincent (**88, 89, 90, 91, 92**), whose work on the function of the vibrissae, olfaction, tactual functions and vision in the maze is too well known to require more than a few examples to indicate its relation to our problem, found that induced asymmetry of vibrissae produced a different distribution of errors than that obtained from normal rats. Rats whose vibrissae were disturbed, though not asymmetrically, were found to have a different error distribution than normal rats. Vincent also found that blind rats gave a different error distribution. A related experiment which confirms Vincent's findings is that of Richardson (**61**). This experimenter also finds that vibrissae are necessary for the initiation of jumping

behavior. Slight aberrations, genetically determined, which would tend to asymmetry, or other disturbing variations in sensory functions, would likely tend to differential errors. (See Yoshioka below.)

Robinson and Wever (**62**) have indicated that differences in visual acuity between pigmented and unpigmented rats are operative in the maze situation. Thus blinds or paths having different visual stimulus characteristics will be behaved to in different ways by pigmented and non-pigmented rats.

Liggett and Liggett (**52**), Vincent (**90**), and others have indicated that rats are able to follow or are disturbed by odor traces. Differences in olfactory acuity, genetically determined, would tend to cause variability in behavior to olfactory stimuli if blinds were differentially weighted in odors.

The effect of capacities and special abilities is indicated by the experiments of Tryon (**77, 78, 79, 80**), who is at present, by selective breeding, producing a group of rats with superior maze ability, and a group with inferior maze ability. As we shall see later (*Organizing Factors*) Krechevsky (**45**) has given experimental evidence that the maze ability differences in these two genetically differentiated groups of rats may lead to different kinds of errors.

Utsurikawa (**85**) has indicated that inbred rats are less active, more savage, more sensitive to momentary auditory stimuli, more negatively responsive to the experimenter, and show less behavior differences between sexes when compared with outbred stock. Stimuli, intra- and extra-maze, which would tend to cause these differential variables to operate will tend to produce different error scores for inbred and outbred stock. For example, the inbred rats would tend to be less upset by the proximity of the experimenter to the maze, thus making fewer errors than outbred rats at the beginning of the maze if the experimenter were habitually in that location. A related experiment will be found under *Extra Maze Factors* which indicates that normal rats tend to make more entrances into those blinds in the direction of, and near, the experimenter.

Yoshioka (**106, 110**), investigating position habits, has presented evidence suggesting that a right- or left-going position-habit is correlated with an asymmetrical arrangement of the cranial bones.

Tsai (**81**) has found that "when a rat turns to the left side of a blind alley at the end of the cul-de-sac, it usually turns, upon leaving the cul-de-sac, to take that path on the left side of the blind alley, and *vice versa*". He finds this tendency present in 84.4%

of the entrances of the first blind on the *first trial*. He concludes that the tendency is brought by the rat to the maze. For further consideration of this factor, which may or may not be genetically determined, see Centrifugal Swing.

The work of Crozier (15) and others on tropisms in rats points to a causal factor. A maze having a slanting floor or alley sides conducive to tropistic reactions will cause differential errors, *if* other factors are relatively impotent.[2]

Crozier also finds that tropistic behavior is more fully present in young than in old rats. Thus age may be a factor correlated with tropistic movement and therefore a causal factor in the problem before us.

Crozier and Pincus (14) in "three series of observations of successive generations of *Rattus norvegicus* indicate that the constants in equations of curves describing the geotropic orientation are characteristic of the strain. Different inbred strains have been obtained for which the respective constants are quite dissimilar."

Slonaker (69) has found that rats are more active at night than during the day. In experiments to be considered it has been found that increased activity increases the speed of running the maze. Differences in speed of running may cause differential errors. For example, the effect of centrifugal swing would likely be increased by greater speed, and more errors would be made into those blinds where this factor operates. (See Contrifugal Swing, under *Physical Determiners*.) Thus it may be that the same maze would yield slightly different error distributions for night and daytime running.

Vicari (87), using inbred strains of mice, finds that the running time of the maze seems to be inherited. Crosses of F_1 and F_2 indicate the likelihood of some form of dominance for the shorter running time.

The work on sex differences is so extensive that we shall mention only that Corey (13) has found that "with respect to 'active time' the males are more variable in their performance than the females". Considering only the factor of activity as it is related to oestral cycles, we may conclude that it may affect some other factors such as centrifugal swing and thus produce differential errors.

[2] It may be pointed out here that whether or not a slight slant to a floor, or the shape of the walls acts as a tropistic stimulus, Ruch (64, 65) has found that it is possible for a rat to differentiate incline differences of only one degree in a maze-like alley. Dashiell and Helms (19) have also indicated this same factor.

II. Physiological Determiners

If the conditioned reflex is to be thought of as a mechanical neurophysiological function, it belongs in this classification. If, on the other hand, it is to be thought of in its greatly expanded form, generally termed "conditioned response", it is in part dependent upon other factors in this list. However it is defined, it has often been used as a predictive concept in the determination of differential errors. A notable example is the chain reflex theory which assumes that conditioning starts at the goal box and progresses back to the starting box, thus increasing the error scores for those blinds at the beginning of the maze.

Liu (**53**) found that the age of greatest maze ability corresponded to Slonaker's (**69**) findings of the age of greatest activity. He says, "it is noted that the relative number of retracing errors increases with age while the number of cul-de-sac errors consistently decreases with age. . . . The younger animals react impulsively, exhibit but little caution, and explore the maze in a headlong fashion, while the older rats move more slowly, and proceed somewhat cautiously, and keep returning to more familiar surroundings after each exploratory excursion." Thus, if retracing errors are included in the error score, those blinds near the beginning of the maze would tend to have a greater frequency of errors for older rats than for young rats. He suggests that the older rats, being larger, are not able to turn about easily in the maze alleys. This relation of size to alley width may be a factor in differential error determination. A blind of such dimensions that an animal would either tend to back out (a form of behavior the writer has observed) or to make several attempts to turn about in the blind, would limit the operation of Tsai's (**81**) cul-de-sac phenomena for that blind (see above), while other blinds which did not limit this factor would tend to produce errors consistent with it.

We have mentioned above that activity is correlated with maze speed. Shirley (**68**) obtained correlations between maze ability, activity, and brain weight. The correlations between activity and time are as high as $.46 \pm .14$. We have mentioned above that differences in speed may tend to produce differential errors.

A large number of experiments have been devised to indicate the relation of drives to maze ability. A number of these we have included under *Goal Functions,* but because of the intimate interrelationship between *drives* and *goal functions* it is difficult to determine their separate natures, and so for the most part we have

followed the classification of the experimenter as revealed by the reference titles.

Washburn (99) has indicated the relationship between hunger and speed of running the maze. On the basis of differences in speed of running the maze and amount of food eaten at the goal, she was able to divide her animals into a hunger-driven, and an activity-driven group. The end result for both groups was the same, *viz.*, running the maze, but the physiological factors motivating the behavior were different for different animals. Washburn, Collens, and Upjohn (100) indicate that the activity-driven animals run faster than the hunger-driven group. (For relation of speed to differential errors see Centrifugal Swing.) Anderson and Smith (1) found that stunted rats run more rapidly than do normal rats. Older rats were found to be less active.

Other factors which might be included within this class are the effect of drugs, sex maturation, etc.

III. Physical Determiners

Schnierla (66) has introduced the concept of "centrifugal swing". Lately, Ballachey and Krechevsky (2) and Ballachey and Buel (2a) have shown that centrifugal swing may be operative with rats in the maze situation. This theory assumes that an animal by reason of a forced turn in the maze is thrown or tends to be thrown against the maze wall away from the direction of the turn, so that upon reaching a bifurcation he is nearer one entrance than the other. This theory assumes that the cause of the deviation to one side or the other in a forced turn may be a function of the centrifugal force of the animal. Besides the effect of speed which would operate to increase the force, the *weight* of the animal may also be effective in increasing the centrifugal force of the turn. Tsai (81) reports a similar behavior (see above) but assumes a different cause, though the reason for the weighting of entrances in both cases is due to proximity to the blind entrance. The consistency with which this theory (centrifugal swing) will predict errors suggests that it is a very important one.

Ulrich (84) has given evidence to support the suggestion that positions and postures enforced upon the animal by the confines of his environment may tend to differential behavior since the direction of behavior forced upon the animal by his positions and postures may weight blind entrances differentially to the degree that they release or inhibit the postures.

Physical determiners as they have been presented here are difficult to separate from maze structure and pattern, but since the factors have been advanced as part of a behavior theory only partially determined by pattern or maze structure, they have been placed in this separate category.

IV. Route and Blind Preferences

DeCamp (**20**) has proven that rats prefer a short path to a long one. Mazes allowing such differentials to operate, such as by alleys so wide as to allow corner-cutting, thus causing the animal to be nearer one bifurcation entrance than the other, will tend to weight those blinds which are nearest to the route of the short cut.

Position habits may well be thought of as preferential, whether due to anatomical variables (Yoshioka, **106, 110**) or to environmental ones, such as goal direction.

Yoshioka (**107, 108**) indicates that rats prefer an angular path to a straight one, and that differences in angularity produce correlated differences in the expression of the preferences. Thus, blinds so situated or so constructed with respect to the true-path as to allow differences in angularity may show differences in error scores due to this preferential factor.

Vincent (**89**) used a maze with blinds and alleys of contrasting brightness and found that one may be dominant or preferred over the other. Thus differences in lighting may influence errors as well as the predetermined preferences. (For further material see Patrick and Anderson, below.)

Route preferences are closely related to goal functions, and are usually, in part, dependent upon them, as indicated by Yoshioka's (**111**) experiments upon direction as a factor in maze solution. He finds that if the goal direction in a T-maze is clockwise, more errors are made into clockwise blinds. In two triangular and equal paths to food, the original preference for one path over the other was found to resist breaking up, if the second habit was away from the direction of the goal, and easily obtained if the second habit was in the direction of the goal. Given two spatially equal paths to food, the rats prefer, under certain conditions, the path nearest to the food position.

Peterson (**59**) has shown that in a maze with long and short blinds, the long blinds tend to be eliminated first. White and Tolman (**104**) under different conditions conclude "that in certain

types of situations at least, long blinds and not short ones are eliminated first". The conditions of their experiment approached a two-way discrimination box.

Tolman, Honzik, and Robinson (75) have indicated that the preference for short blinds over long ones is not independent of reward value. Hungry rats were found to eliminate long blinds before, or as soon as, they did short ones, whereas with less hungry rats the reverse was found, *i.e.*, they tended to eliminate short blinds before they did the long ones. Yoshioka (109) has indicated that distance discrimination is subject to Weber's Law. If preferences for short blinds are determined by the discrimination of distance differences between long and short blinds, those blinds so constructed as to be within discrimination limits will have different error frequencies than those blinds which are below the discrimination threshold.

Tolman and Sams (76) have presented evidence that the temporally shorter of two spatially equal routes to food is preferred by the rat. A gate, curtain, or other maze structure so placed or operated as to delay an animal on one side longer than the other would tend to cause the animal to seek the temporally shorter side, and thus weight entrances in that direction. (See *Maze Structure and Pattern.*)

Dashiell (17) and Dashiell and Bayroff (18) have suggested that rats have a forward-going tendency, and that this factor tends to increase errors into those blinds in a forward-going direction, while blinds not in this direction tend to have fewer errors. Vincent (91) observed similar behavior in the elevated maze. Dennis (21) found, as did Dashiell (17) that route preferences of this nature are subject to considerable variation.

The theory of "least effort" or what Gengerelli (27) calls the "law of maxima and minima" may be a deciding factor in this matter of route preferences. Tsai (82) has given evidence from the maze which seems to substantiate this as a causal factor in determining errors.

V. Goal Functions

Elliott (24, 25, 26), Williams (105), Bruce (6), Tolman, Honzik and Robinson (75), Tolman and Honzik (73, 74), Blodgett (3), and many others have given evidence that maze learning as expressed in time and errors is highly correlated with reward value.

Hubbert and Lashley (38) reported that in the circular maze rats ran with their heads toward the center and attempted to climb

the inner walls, but never the outer ones. We have already referred to Washburn's (99, 100) studies of hunger in relation to maze learning. Dashiell (16), studying transfer factors in maze learning, found that in a series of changing mazes with the food box in one constant direction from the entrance, " a blind alley turning toward the general direction of the food box is more likely to be entered than one turning away from this general direction in about the ratio of three to one. This developing tendency forms a factor in the transfer of maze training." Dashiell (17) in another series of experiments bases his theory of orientation upon the goal direction.

Elliott studied the effect of change of drives (26), change of reward (24), and changes in the appropriateness of the reward (25). All these changes were found to affect errors and time. In so far as these variables affect time we assume that they will cause differential errors for reasons given above.

The effect of the introduction of reward by Blodgett (3) indicates that without reward latent learning is taking place, though neither in time nor errors is this evident until the reward is introduced, when both time and errors immediately drop to the control group level. Such learning without reward indicates that other factors besides speed, goal functions, etc., are effective in latent learning, but that differential errors depend upon these factors, since without reward all blinds tend to have similar error scores.

Haney (30) in a somewhat similar experiment allowed his animals to live in the maze without reward. This familiarity with the maze was found to result in error and time scores similar to the control group when food was introduced as a reward, again pointing to the close relation between speed and reward.

Hunter (40) found that blind alleys in the direction of food were entered more frequently. Tolman, Honzik, and Robinson (75) found that reward value influenced the frequency of entrances into long and short blinds. (See above.) Tolman and Honzik (73) have reported that the frequency of entrances into food-pointing and non-food-pointing blinds is correlated with the value of the reward, and that introduction and removal of reward likewise influences the frequency of entrances into food-pointing and non-food-pointing blinds (74).

Washburn and Ebersbach (101) have evidence to indicate that if the direction of the initial pathway is toward the goal, the orientation toward the goal is increased, thus giving added weighting to food-pointing blinds.

Sharp (67) has found that integration of the maze habit is subject to variation due to the number of trials run. If the number of trials per day is increased considerably, disintegration of the maze habit occurs, the degree of disintegration varying directly with the number of trials per day. This same effect is obtained when the reward is removed. Both causes of disintegration may affect differential errors, since error differences between blinds become negligible when the maze habit is disintegrated.

Williams (105) found that rats would run to a food-box in which they had been fed previously, even though no food were present in the box. The relation of this reward conditioning of some feature of the maze to differential errors is obvious.

The goal gradient theory of Hull (39) tends to produce differential errors. Spence's (70) analysis of the goal gradient theory with respect to the linear and other forms of mazes further supports it as an important theoretical determiner of differential errors.

VI. Emotional Factors

Higginson's (34) work upon the after effects of certain emotional stimuli indicates that the primary stimulus producing an emotional disturbance does not need to be continuous with the running, or to be intra-maze, to disrupt learning. In one series of experiments the rat was placed in a jar, his tail pinched and his nose tickled. In another the rat was placed in a cage with a cat. These stimuli introduced before the maze was run increased the time in running the maze and for learning it, the degree of variability of performance from trial to trial, the total distance traveled, and the number of errors. The emotional response was found to be negatively adaptive, thus, it may be, introducing differential rates of adaptation.

Patrick (57) sounded a buzzer at one side of a maze and found that animals tended to explore the opposite side of the maze. Further, he found that when animals are under a drive incidental emotional stimuli tend to cause excess activity, while under conditions of no drive they tend to decrease activity. (See relation of activity to speed and errors, above, and Patrick and Anderson, *Extra-Maze Factors.*) We have referred to the temperamental differences determined genetically in Utsurikawa's (85) work; and Liu's (53) findings of increased caution with age.

Jackson (42), studying factors of transfer, found that effects of handling transferred. The animals became negatively adapted to

handling effects, thus reducing the variability of responses. Hubbert (37) in analyzing error eliminations in the maze throws out entrances into blind number 1 as entrances are claimed to be 50-50 due to emotional disturbances. If this observation is correct we assume that as the rat traverses the maze he will be less upset, thus decreasing errors for the latter part of the maze.

Many of the above factors are related to extra-maze factors, and many items under that class belong here.

VII. Extra-Maze Factors

In this class are included all the extra-maze stimuli which would cause distraction, emotional upset, breakdown of the maze habit, orientation, etc. The effect on maze performance by the disruption of extra-maze cues has been known for a long time. Watson (103), Carr and Watson (11), Hunter (40), Carr (9), and many others have indicated the importance of extra-maze cues by the rotation of the maze, and by other methods. Cues of this nature may weight certain blinds by proximity or direction.

Carr (9) finds the following changes to affect maze learning: changing the position of the living cage; cleansing the maze; uncovering the maze; decreasing illumination; changing the position of the maze; and changing the position of the experimenter, of which he has this to say: "Disturbances occurred only at that point in the maze path near which the experimenter stood. The path previous to and after this critical point was traversed normally. All error deviations were in the direction of the experimenter."

Leuba and Fain (49) have found that the relation of the position of the living cage to the maze is an important factor. In this experiment when the living cage was rotated with and attached to the maze no disturbance was found. When the maze was rotated independently of the living cage disturbance of the maze habit occurred. If orientation is partly determined by the living cage position, (as Dashiell, 17, suggests it may have been in this experiment), then blinds entered or avoided because of this factor will be affected.

Patrick and Anderson (58), using a T-maze, introduced stimuli consisting of a bright light focused over the true path, a shadow over the true path, a buzzer outside the maze, change of position of the experimenter, a white panel used interchangeably with a black panel in the black wall of the maze, and rotation of the maze. One group was run with the stimuli constant, another with them inconstant, four out of five trials. The latter group was not disturbed

by changes, but the former group was markedly disturbed in time and errors. They conclude that "From the data . . . it appears that the white rat learns not the maze pattern alone, as such, but that he learns this pattern as it is related to other stimuli acting constantly along with the maze pattern at the time. . . . A *sudden shift of incidental stimuli* acting along with the maze pattern which is being learned will, after learning has taken place, throw the animal off and cause an excess of errors made in succeeding trials. . . . *There seems to be a tendency for the loci of excess errors made to be distributed about the points of incidental stimuli* which may themselves be responsible for the excess errors." (Latter italics ours.)

VIII. Pre-maze Factors

The living cage environment (see Carr above) may well cause differential errors. The amount of "maze-brokeness", handling, regularity of feeding, etc., are also factors to be considered. That preliminary training has an effect upon the initial error score is well known. Warden (93) finds that pre-feeding in the food-box reduces preliminary exploration, affects the shape of the learning curve, and reduces emotional upset.

IX. Temporal Factors

We have considered elsewhere some of the factors that cause differences in speed of running, such as the effect of age, activity, reward values, etc. Hull (39) in his goal gradient theory includes the factor of time. The animals tend to run faster in the latter part of the maze than in the first part. It is likely that this factor would correlate with centrifugal swing, since greater speed would tend to increase the effect of centrifugal swing.

Another temporal factor is delay. Watson (102) found that delay in feeding (not a maze situation) increased activity. Warden and Haas (97) indicate that delay in the maze of five minutes causes disruption of the habit. Hamilton (29) investigated this same factor in relation to maze learning and found that delays from one minute to seven minutes had little effect, but that delays less than one minute were effective in disturbing the error scores. A delay in any particular part of the maze would therefore disturb the error frequencies for blinds intervening between this location and the goal, but would, of course, not affect those blinds previous to the delay point in the maze.

A temporal factor different from the above is the distribution of practice. We have seen that an increase in the number of trials per day causes disintegration of the maze habit. Ulrich (**83**) finds that most efficient learning takes place when the trials are distributed over several days. Lashley (**48**), studying the relation of the distribution of practice to the rate of learning, finds that 49.05 per cent of the errors made in successive trials were diverse. "In successive trials made on the same day 44.48 per cent of errors made in these successive trials were diverse. The trials separated by a 24-hour interval are thus seen to include 10 per cent fewer duplicate errors than those without intervening time. A greater diversity of activity occurs where successive trials are separated by a considerable interval of time than when they follow each other immediately."

Clements (**12**) has shown that, given two spatially unequal paths, the rat's normal preference for the shorter of the two can be broken down by delay in the shorter path. In the maze, differences in the frequency of entrances into blinds due to length could be varied by delay as the result of maze structure, such as gates, curtains, etc.

X. Maze Structure and Pattern

Under this heading, to be complete, should be included all the reasons and factors which caused changes from the early forms of mazes to those now in general use (**98**). Hamill (**28**), using a maze with a starting door, "observed . . . that the animals soon established to—they even clawed at—the side on which the door opened". Blinds adjacent to that side of such a door would presumably be weighted.

The work of Vincent (**88**) clearly indicates that different error distributions are to be expected in elevated and alley mazes. The rats tend to cling to one edge, etc. Miles (**56**) made a direct comparison between ability on an elevated and an alley maze of the same pattern. His results on the entrances into the same blinds for the mazes show considerable variation, though there is a general tendency for the order of elimination to be the same in both mazes. He also states that "a blind which represents a turn in the direction of food and which is located near the goal end shows an increasing ratio of errors, compared with other blinds, as the learning progresses. Such a blind brings out the shortening tendency in the maze habits of rats and causes 'anticipatory' errors. These results are found with both alley and elevated mazes but *seem stronger with the latter instrument.*" (Italics ours.)

From Dennis' (21) experiment we learn that variability of performance may be related to width of alley.

Carr (8) in his experiments on the distribution and elimination of errors concludes that the attractiveness of cul-de-sacs are due to peculiarities of construction or position and must be interpreted in terms of the animal's organization in reference to them.

The importance of turn sequence is indicated by Hamill (28) who used a maze that varied only in the length of paths. He maintains ". . . it seems apparent that changes in turn sequence occasion interference; and that training in a maze with longer distances between turns does not interfere to a marked degree with subsequent running of a second maze of identical turn sequence but shortened distances between patterns." He explains the occurrence of differential errors as due to food-pointing blinds, shallow blinds, effect of last correct choice (see below), and compensatory errors. When rats were transferred to a mirrored pattern of a first maze, some general tendency to go in one direction was observed, thus weighting blinds in that direction. (See *Goal Functions.*) Warden and Hamilton (96) find that the difficulty of the linear maze varies inversely with the length. Heron (32), however, points out that this is not a fair test, since the pattern was alternating, right and left choices. The longer maze (more units) would tend to favor right and left sequences of choices due to increased frequency and opportunity for solving the sequential order. Any blind not in this order (right, left) would presumably have a high error frequency. The next experiment seems to substantiate this conclusion.

Liggett (51), using a special form of unit maze, finds that "the elimination of errors apparently is influenced by sequential pattern, as well as by position in the maze, and inherent difficulty of position in regard to the true path".

Ruch (63) has reported that an excess number of right or left turns in the linear maze produces differential errors in accordance with the overweighting of right or left turns.

Dennis (22) indicates that after the first few runs the longer the maze the greater the speed with which it is run. He also finds that "partial elimination and head movements were more frequent in the longer forms of the maze". Partial errors may be caused by emotional factors also, and if this type of error is included in the error score we may expect a different error distribution.

We mention again that Washburn and Ebersbach (101) found the direction of the initial pathway to influence the orientation toward the reward.

Valentine (**86**) found that punishment for incorrect responses tended to a more rapid elimination of errors. Any structural features tending to frighten or injure the rat would cause differential error scores to appear. The behavior of rats that have been hurt by food box doors is well known.

Carr and Koch (10) suggest that the *making of errors* is beneficial to learning. Thus, at what particular trial a rat begins to make errors into a given blind will perhaps determine his rate of final elimination of that blind.

Mazes allowing visual exploration of blinds may cause differential errors. Dennis(23) observed that "seeing rats corrected their errors before reaching the end of the blind alleys, whereas blind rats ran to the end". (For further work on this factor see Robinson and Wever above.) The observations of Tsai (**81**) on cul-de-sac behavior which we have referred to under *Genetic Factors* possibly belong here also. Centrifugal swing is another important factor which should be included in this class as well as under *Physical Determiners.*

We must include here another factor which will give the same general results as those to be expected under the goal gradient hypothesis, *i.e.,* chance. Peterson (**60**) has suggested that due to the form or structure of the maze an animal running by chance alone may make more errors at the beginning than at the end of the maze if retracings are allowed to occur.

Higher Behavior Possibilities

Factors predictive of differential errors in the following list are included under this separate heading because there seems to be no convenient way to justify including them under any of the other categories we have discussed. To be sure, many of the factors involved in these behaviors to be described are, or should be, included in the above lists, but the *organization* of them seems to be a *discrete* factor. They are included because many of them give us insight into the causes of differential errors.

XI. General Orienting Factors

Dashiell (17) has presented two factors that may be classed under this heading. The first is an initial orientation or set at the maze entrance, and the second, the goal direction. The goal direction is in part dependent upon the initial orientation for its reference point. Maze direction, we may note, may well be a function of other factors we have listed above, but it is a *way* of handling such fac-

tors that may possibly cause differential errors by weighting blinds consistent with it.

Another type of orientation which for want of a better term we shall call "specific locale" is concerned with the rat's knowledge of a specific place in the maze. Lashley (47) reports that rats allowed to escape from the maze near the starting box tended either to take more or less direct routes to food over the maze, or to reënter the maze at locations that got them nearer to the goal, and from there on they ran the maze correctly.

Honzik (35) has reported on the effect of introducing short-cuts in the maze. Using blind rats on an elevated maze, he introduced new paths leading in the direction of the goal, thus eliminating portions of the maze and presenting a shorter route to food. The units used throughout the maze are interchanged, and other controls are introduced to eliminate the possibility of specific cues. He finds that some rats that have had a short-cut the previous day, but are now running the former maze pattern (before the short-cut) *stop at the place* where the short-cut had been the previous day.[3, 4] Honzik believes, following Lashley, that some intraneural mechanism is responsible for position knowledge in the absence of specific cues.

Tryon (80) and others have found evidence suggesting that rats are capable of forming abstract generalizations of the maze pattern. Using a multiple T-maze he excluded specific cues by interchanging units, excluding vision, etc. He finds that his animals are still fairly capable of running the maze correctly when parts of the maze pattern are disturbed. (See Honzik above.) He believes that this behavior indicates that the rat has a generalization of the gross spatial sequences and directions of the maze pattern. This theory is somewhat similar to Dashiell's (17) except for the generalization of the space directions intervening between the starting box and the goal. Blinds consistent with the space generalizations may have different error frequencies from those inconsistent with them.

[3] We are indebted to Mr. Honzik for permission to cite this observation of "specific locale" behavior. Mr. Honzik has not included this observation in the reports referred to, but has indicated its occurrence to the writer. The unique character and frequency of this behavior seems to preclude chance explanations. The writer assumes the responsibility of terming this behavior "specific locale".

[4] A somewhat similar finding has been reported by Brown (4, 5). Using human subjects in a foot-maze he finds that a long alley serves as an identifying point in the maze, and that an increase in speed and a decrease in errors follows such a feature in the maze. This factor may also belong under *maze structure.*

Another experiment which possibly indicates some of these generalizing factors is Macfarlane's (**54**). Macfarlane ran animals in a maze that could be filled with water, thus making it a swimming maze. He found that animals could learn the maze either by running or swimming, and then swim or run the maze with corresponding accuracy. Because the kinesthetic pattern of acts is so dissimilar for the two methods of traversing the maze, he concludes that kinesthetic patterns are *not necessary* for correctly running the maze. Such experiments indicate that either the rat has abstracted the pattern or that cues may function vicariously.

XII. "Expectancy"

Vincent (**88**), Miles (**56**), and many others have indicated the effect of anticipatory errors. The writer (**7, 7a, 7b**) reported the effect of the last correct choice in the linear maze. The direction of the last correct choice in the linear maze causes errors to be of a higher magnitude on *that* side of the maze than on the other. Behaviorally each choice point (depending on the stage of learning) is reacted to with the same behavior that is appropriate to the last choice point of the maze. This behavior was called "choice point expectancy". Recently, Spence (**70**), in common with the writer (**7, 7a**), observed that this factor is operative in the Warden form of the linear maze, and can be identified in Warden and Cumming's (**95**) experiments. For our purposes it can be described as the effect of the last correct choice of the linear maze upon all the choices preceding it. This factor is partially determined by the pattern since blinds on the last correct choice side of the maze are affected.

XIII. Organizing Factors

Insight can be thought of as a determiner of differential errors. It has been observed many times that an animal will make a high frequency of entrances into a given blind, and then *suddenly* eliminate that blind. As expressed in the error score this behavior has all the characteristics of insightful behavior. Higginson (**33**) has reported that when a new path is presented to a rat—the path leading in the direction of the goal—the rat will tend to take it upon its first presentation. Helson (**31**) observed a few cases of insight. When rats were shocked upon entering the wrong compartment of a discrimination box, they made their exits, not by returning out through the door and thus over a live grid, but by climbing over a high middle partition into the food box. The

similarity of such behavior to goal orientation is pointed to by the experiments of Hubbert and Lashley (**38**). Vincent (**88**), Miles (**56**) and others have commented upon the entrances into blinds near food in elevated mazes, and attempts to jump the intervening distance between the paths and the food-box. Such behavior may be a special case of insight.

Further proof of the validity of considering rats to have insight is to be found in the experiments of Hsiao (**36**), and Tolman and Honzik (72). These experiments were designed to " prove " the ability of the rat to have insight and do not depend upon casual observation.

Maier (**55**) has indicated the possibility of reasoning in rats. Probably the most valid of such experiments on the higher functions are those of Krechevsky (**43, 44, 45, 46**) on " hypothesis " in rats. In this series of studies Krechevsky has proven that given the same set of variables (in this case a four unit discrimination box which was in all ways, except for the visual discrimination cues, similar to a four unit Y-maze) rats will, in their presolution behavior, form systematic behavior units which include all the possible hypotheses that can be made for the problem. Thus, irrespective of which of the factors (cited above) are involved, the *way* in which they are combined and utilized systematically in attempting to solve the problem will cause differential errors. In the maze some rats may be responding to visual hypotheses, some to spatial, or other types of hypotheses, and blinds differentially consistent with these hypotheses will have different errors.

Recently Krechevsky (**45**), using " bright " and " dull " rats from Tryon's selected stock, has shown that this factor (" hypothesis ") is not independent of genetic factors. The " dull " animals do not take to spatial types of " hypotheses " readily, but rather they form visual or other types of " hypotheses ". This would indicate the possibility of these " dull " rats fixating responses to olfactory, visual or other cues in the maze rather than spatial ones. The " bright " group, on the other hand, tend to spatial " hypotheses ", and these animals would supposedly avoid those systematic errors in the maze which are due to differential visual, olfactory, or other non-spatial characteristics of the maze.

We note that most of the factors listed above could be included under two or more categories and also that each factor affects some other factor or factors. We have refrained for the most part from duplicating these factors under different headings. We have not

always indicated the exact functioning of some of the factors in causing differential errors, but enough explanation has been given, we hope, to indicate how these factors may operate.

Summary and Discussion of Factors

In order to obtain a comprehensive view of the complexity of this partial list of factors, let us summarize them.

I. *The Genetic Make-up of the Organism.*
1. Behavioral propensities of the species.
2. Special organs.
3. Aberrations of sensory organs.
4. Sensory acuity.
5. Special abilities and capacities.
6. Temperamental differences.
7. Anatomical asymmetry and position habits.
8. Cul-de-sac phenomena (Tsai).
9. Tropisms.
10. Activity cycles.
11. Reaction time or speed.
12. Sex differences.

II. *Physiological Determiners.*
1. Conditioned reflex.
2. Age.
3. Activity.
4. Retracings.
5. Body size.
6. Maze speed.
7. Drives.

III. *Physical Determiners.*
1. Centrifugal swing.
2. Weight.
3. Postures and positions.

IV. *Route and Blind Preferences.*
1. Preference of short to long path.
2. Position habits.
3. Angular path preference.
4. Cue dominance.
5. Resistance to modification of a goal direction preference to one in opposition to the goal direction.

6. Preference of path in spatial proximity to goal.
7. Error frequency of long versus short blinds.
8. Reversal of long versus short blind frequencies due to pattern.
9. Long versus short blind frequency dependent upon reward value.
10. Distance discrimination and Weber's Law.
11. Temporally shorter path preference.
12. Forward-going tendency.
13. Route variability.
14. Law of " maxima and minima ".

V. *Goal Functions.*

1. Bodily orientation to goal direction.
2. Food-pointing blinds.
3. Appropriateness of reward.
4. Latent learning.
5. Food-pointing blinds and reward value.
6. Direction of initial pathway.
7. Disintegration and reward.
8. Conditioned reward.
9. Goal gradient.

VI. *Emotional Factors.*

1. Extra-maze and pre-maze stimuli.
2. Rate of negative adaptation to emotional stimuli.
3. Avoidance of areas in proximity to emotional stimuli.
4. Emotional stimuli and activity.
5. Age and caution.
6. Handling.
7. Decrease of emotional disturbance with progression in the maze.

VII. *Extra-Maze Factors.*

1. Extra-maze cues.
2. Position of the living cage.
3. Maze cleansing.
4. Illumination.
5. Position of experimenter.
6. Constant and inconstant incidental stimuli.

VIII. *Pre-Maze Factors.*

1. Living cage environment.
2. " Maze-brokeness ".
3. Handling.

4. Regularity of feeding.
5. Preliminary training.

IX. *Temporal Factors.*

1. Age.
2. Activity.
3. Reward value and speed.
4. Goal gradient (speed).
5. Delay.
6. Distribution of practice.
7. Effect of delay upon preference for shorter route.
8. Preference for temporally shorter path.

X. *Maze Structure and Pattern.*

1. Mechanical features.
2. Elevated and alley mazes.
3. Increase of goal orientation in the elevated maze.
4. Width of alleys.
5. Turn sequences.
6. Excess of right or left choices.
7. Length of maze and speed.
8. Length and partial error scores.
9. Punishment.
10. Effects of error making upon rate of elimination.
11. Structure permitting distance receptors to function.
12. Chance.

Higher Behavior Possibilities

XI. *General Orienting Factors.*

1. Initial set and goal direction.
2. Specific locale.
3. Identifying feature.
4. Abstraction of maze pattern.
5. Vicarious functioning of cue patterns.

XII. *"Expectancy".*

1. Anticipatory errors.
2. Choice-point expectancy in the linear maze.

XIII. *Organizing Factors.*

1. Insight.
2. Reasoning.
3. Hypothesis.

In the above summary are ninety-three possible factors which have been or may be advanced as causes or predictive concepts in the

determination of differential errors. All of them are supported by some experimental evidence. The list could be increased, but as it now stands sufficient factors are included to indicate the complexity of the maze situation. Even if many of the factors given prove to be incorrect, the complexity of the maze problem in terms of the number of factors will still remain large.

This complexity is not a function of the number of factors alone, but also of the *inter-dependences* and *interrelations* existing among them. Nowhere in the list can we find factors, other than some of the genetic ones, which are independent of others. The maze cannot be run without some motivation. The introduction of motivation affects speed and errors, which in turn affect, and are affected by, numerous other factors. We shall examine this in more detail later.

Considering but one group of factors, for example the genetic, the number of possible genetic combinations in so complex an organism as the rat is admittedly *very* large. Adding to this the possible combinations of the list given above, the resulting complexity is so great as to discourage attempts to solve it.

It is usual to describe maze behavior in terms of a few inclusive concepts, or measurable variables. We shall indicate a few of these, and examine some of the assumptions that are made when they are used.

Genetic variables which influence individual differences in maze ability are for the most part ignored in animal maze problems. A bare statement of the stock from which the sample was obtained is usually thought to be sufficient, and this because the work entailed in obtaining a group of animals with the same genotypical characteristics is difficult, if not impossible. Nevertheless it is usually assumed that the genetic differences are so small as to be uninfluential in determining differential errors. Thus in most experiments, without any knowledge of the effect of this factor, it is assumed to be constant throughout the experimental population. (See Krechevsky above.)

Time is another often used variable that measures, as we have attempted to indicate, the effect of a number of dependent and independent factors. Time scores are often used to indicate differences in speed of running. Time scores may not only measure differences in speed of running, but may measure at the same time differences in maze pattern, activity, age, genetic differences, delay, etc., which are the causal factors determining one effect (time).

Goal functions are likewise usually thought of as constants, *e.g.*, food position. The reward value is assumed to be constant and is described in terms of the amount of food available at each trial, or the

amount of time allowed in the goal box. But, as we have indicated, the reward value is *not a constant,* but varies as other factors vary. Most evident is the variation in physiological needs from trial to trial or within a given trial. Others are delay in the maze, effect of pattern, etc. We need not again emphasize the interrelations of these factors.

Maze structure or *pattern* is another constant or variable, depending upon the experiment, which is often used descriptively as though it were *one* variable or factor, and not, as the above list indicates it may be, a sum or function of numerous factors.

Errors[5] are another and more important measurable unit of behavior. Each error in the maze is the sum or the inclusive category which indicates in unit manner the total sequences of behavior resulting in the deviation from a true path into a blind. As such it is a descriptive designation of the total effect of numerous causes. Individual entrances into particular blinds are, like other broad descriptive units of maze measurement, due to dependent and independent causes. They are a higher category of measurement since they are the effects of all the other broad categories as well as the sub-causes within the latter.

These five variables, *genetic, time, goal functions, maze structure* or *pattern,* and *errors* are often the measurable variables applied to maze analysis. An examination of the list of factors given in the first part of the paper reveals that most of them will go under some one of these five inclusive variables, and often under two or more of them.[6] All of these variables are here represented as functional units, *e.g.,* maze structure as a behavioral pattern.

[5] Errors are used here with two different meanings. When we are concerned with *differential error scores* we are using errors in the sense of a measuring scale. That is, they are measures which are outside the experimental situation. The other meaning, which we are also using here, is descriptive of behavior. A "behavior-error" is functional with respect to other "behavior-errors". A "behavior-error" (going into a blind) may affect the entrances or non-entrances into subsequent blinds. A measuring error can never be functional. It is a descriptive term like inches or liters. The functional errors are, of course, perfectly correlated with the measuring scale errors. This same distinction may be applied to time.

[6] It is not the purpose of this paper to advance the use of the five variables as valid measures of behavior (see below) or to establish them as true indices of the total factors which make them up. Our purpose is merely to show that these often used variables add to the complexity of maze analysis rather than simplify it. Other variables than those mentioned here are often used, as well as the more remote factors which are part of them. We do not mean to imply that this is an all-inclusive list.

The use of such variables in analyzing differential maze errors may not indicate why they are made or allow for prediction of differential errors, since individual errors are due to causes which are inconstant and which are included in the measurable variables without discrimination.

We have indicated that speed of running the maze (time) affects errors (for many reasons not indicated by gross measurable variables such as the five given above) and that errors are also affected by goal functions and pattern functions. But notice that errors may affect speed, and pattern may affect speed. Also *the cause and effect sequence may be circular*. The goal may affect speed which in turn affects errors, the latter further affecting speed, etc. The importance of such sequences of cause and effect to theoretical psychology is obvious.

These causal relationships can be found to exist in four of the main gross variables, the exception being the genetic. The causal directions of the genetic variables are relatively fixed and constant, though variable in their expression, and since in the maze situation they can be causes but not effects they are fundamental in the determination of differential errors. By this we do not mean to imply that the environmental situation is not also fundamental; it is the medium for allowing the genetic factors to operate, and for modifying their operation.

Time and errors together present unique characteristics. Time and errors cannot be obtained independently of each other. Errors consume time, and as we have indicated, speed of running (time) is a cause as well as an effect of errors for the whole maze or any part of the maze. This fact, together with our contention that many other variables operate within time and errors, seems to indicate that their use as measurable units in maze analysis *may not lead to reliable predictions of differential errors.*

Maze structure or pattern, and goal functions as expressed in behavior, are, like time and errors, inseparable and complex. As we have noted, even in the linear maze designed to overcome the directional effect of food position, animals behave as though food were at one side. Without changing the position of the food we can (by increasing or decreasing the number of supposedly homogeneous maze units) change the direction of the last correct choice in the maze. We then obtain behavior like that which results from changing the position of the food. Thus, though geometrical symmetry and equality is in the maze design, behaviorally the pattern is asymmetrical and non-homogeneous (Yoshioka **111**, Buel **7**, Spence **70**).

We cannot be sure whether, for the rat, the food position changed, or the pattern changed. For predictive purposes in other mazes this knowledge is essential.

It is well to note that no theory of animal learning can accurately predict the number of individual errors in any particular blind, unless the factors causing entrances into that blind are so heavily weighted that other factors cannot operate, *i.e.*, individual variations in behavior become zero. When we consider the complexity of but five gross variables we should expect this result. The further knowledge that these five variables may be made up of innumerable and uncontrolled other variables indicates that the accurate prediction of individual scores for any particular blind is an impossible task. We may further assume that prediction of average group scores for any particular blind will vary with the degree of unpredictability of the individual rats. (For further discussion of group scores, see below.)

So far we have considered the factors as having constant weight. But some factors are known to be more potent in determining behavior than others. *A thorough analytical examination of the maze demands that not only must the factors themselves be identified, and the relationships existing among them be known, but also the degree to which they contribute to variations in behavior.* It can be shown that these weights are *not* independent of one another. An animal will tend to make fewer entrances into a long blind than a short one if well motivated by hunger and an adequate reward. But, if the adequacy of the goal or the drive is changed, thus reweighting the reward, the preference for short blinds over long blinds undergoes a change.

Tolman (71) has recognized this difference in weighting and has given it the term "demand value". Value is determined by the degree of persistence or docility for given instances of demand objects or situations. Lewin (**50**) has also recognized the importance of this factor and has in his vector analysis of behavior weighted the vectors with a valence. By valence is meant the force or demand operating in any given vector toward (positive valence) or away from (negative valence) some object or environmental feature. Thus, for each factor, two variables must be determined: (1) the relationships with other factors, and (2) the weighting or degree to which it contributes to behavior.

Krechevsky's experiments on "hypotheses" in rats are illuminating to the meaning of total error scores as well as individual scores. Under the conditions of his experiments (insolvable problem) it is possible to identify the systematic behavior of individual

rats. Each rat behaves differently in systematic ways, yet the total or average error scores for each rat for the whole problem are nearly identical. In other words, the acts necessary to reach the goal may be shown to be disparate even though the total or average individual scores for the whole problem are the same, or nearly so. The total error score for the group can be predicted, and the total error score for the individual rat may also be predicted within limits. The individual rat's error behavior (differential errors) contributing to the score for the whole problem cannot be predicted. Some rats were given to "spatial hypothesis" of which there were several kinds, or to "visual hypothesis" of which there were also several kinds.

In a solvable problem the same difficulty of predicting individual errors is apparent. In the linear maze the individual rat's score for any given blind can be predicted *when* the effect of the last correct choice has so weighted blinds on that side that no animals fail to make entrances into them, and no animals enter blinds on the other side. When learning begins to take place, and differences begin to appear in the behavior of individual rats, no individual prediction is possible. A further fact to note is that the trial at which a given animal will make all the errors on one side and none on the other is unknown, since the factors contributing to that behavior at a given trial are not controlled, and are not identified.

Studies on the order of the elimination of errors in the maze indicate that we cannot even predict for the group what will be the exact order of blind elimination. We must be content with a trend (Spence, **70**).

If the above reasoning is correct, individual psychology and differential error analysis as applied to the maze problem can never be exact actually or theoretically, since the number and complexity of the variables is too great to control properly and measure, and the holding of one factor constant cannot be effected without altering another, *e.g.*, time and error.

Considering group scores for the whole maze, we may reasonably expect to predict with some degree of accuracy, since the factors causing individual variation tend to cancel one another. A long maze is more reliable than a comparably short one, which may be due to the fact that more opportunity is present in the long maze for self-cancellation of factors causing variation to take place. Correlations of individual blinds with each other are low, while correlations of the first half of the maze with the second half are high. Again, the correlations obtained by using the total error scores of the whole

maze for odd and even days are high. The factors causing individual animals to enter, or not to enter a given blind are too numerous and too complex to yield high correlations between individual blinds.

The *average group score* for a particular blind can be predicted for subsequent groups for that *particular* maze and duplicated procedure. But, as we have stated before, our prediction does not contribute much of general theoretical value since *we cannot predict without considerable error for any other maze or for the same maze under different conditions.*

The tendency of animal psychology is at present directed toward two points of view. One is interested in a careful analytical study of factors contributing to behavior, and the second is interested in a more inclusive and unified explanation of behavior (*Gestalt*).

We have indicated that analytical study of the maze, in so far as it is concerned with differential errors, becomes more complex as more factors are found, and that it is already so complex as to cause predictive theories to have extremely large errors.

The gestalt view of behavior seeking to unify the factors into functional wholes does not attempt to determine the minute causes or features of the unified behavior, since the whole may be a determiner of its parts. For example, Lewin (**50**) contends that directive bio-physical forces are acting upon the organism, causing variations in its behavior. The direction of the behavior is dependent upon the valences and topological positions of the forces acting upon him. Thus, an animal separated from an object of positive valence by a barrier will attempt to break through, or otherwise surmount the barrier that inhibits the release of the positive force of the desired object. The barrier at first has no valence, but as it continues to offer resistance to the positive vector it gradually acquires a negative valence operating in the opposite direction to that of the positive vector of the desired object. Finally, if the barrier is not overcome, a state of equilibrium will exist between the negative and positive vectors. The organism can now be influenced by heretofore relatively impotent forces. He may seem to give up, or he may seek a tool or roundabout method with which to overcome the barrier. These latter forms of behavior are also directed by vectors of proper valences.

The gross activity of the animal is here important. The sequence of acts comparable to the individual blind scores in the maze is not included, but the behavior in terms of the total maze score is comparably expressed. In other words, the vector analysis is not analytical in the sense of being able to predict the individual behavior

acts necessary to achieve the goal. In the maze the situation can be expressed somewhat as in the following paragraph.

The food, or goal, has a force or valence operating in a certain direction determined by the confines of the maze (barrier). The blinds and walls acquire a negative valence as they continue to obstruct the release of the positive vector (food). Finally, these negative vectors equal the positive one of the food. At the same time, the true path is acquiring a positive valence. The blinds are finally eliminated in favor of the positive vector of the true path.

The above admittedly incomplete application of the vector analysis to the maze gives us no information as to the *rate* at which blinds and true paths are acquiring valences, nor does it indicate for the complex situation of the maze the many directions the vectors may be operating in, due to the mutually impinging and opposing forces. As long as we are content with the positive vector of food and the true path, and the negative vectors of the blinds without examining them individually we may possibly be able to predict the gross errors for a large population. The acts and their causes making up that total (errors) are again too complex for analysis.

Thus, whether one takes the extreme analytical view or the more unified gestalt view, the complexity of causation in differential errors remains overwhelmingly great. Neither viewpoint seems to add to our ability to predict individual blind errors.

The maze, if our analysis is correct, seems to be a useful device for differentiating groups, but because of its complexity does not lend itself to analytical study. It will indicate behavior trends for groups but it will yield practically no reliable predictive concepts of individual behavior. We hesitate to generalize this statement, but our findings suggest that this criticism may be found to hold for any instrument that may be devised to measure behavior, human as well as sub-human.

BIBLIOGRAPHY

1. Anderson, J. E., and Smith, A. H., Relation of Performance to Age and Nutritive Condition in the White Rat. *J. Comp. Psychol.*, 1932, **13**, 409–446.

2. Ballachey, E. L., and Krechevsky, I., "Specific" vs. "General" Orientation Factors in Maze Running. *Univ. Calif. Publ. Psychol.*, 1932, **6**, 83–97.

2a. Ballachey, E. L., and Buel, J., Centrifugal Swing as a Determinant of Choice-Point Behavior in the Maze Running of the White Rat. *J. Comp. Psychol.*, 1934, **17**, 201–223.

3. Blodgett, H. C., The Effect of the Introduction of Reward upon the Maze Performance of Rats. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 113–134.

4. BROWN, W., Auditory and Visual Cues in Maze Learning. *Univ. Calif. Publ. Psychol.*, 1932, **5**, 115–122.
5. BROWN, W., Spatial Integrations in a Human Maze. *Univ. Calif. Publ. Psychol.*, 1932, **5**, 123–134.
6. BRUCE, R. H., The Effect of Removal of Reward on the Maze Performance of Rats. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 203–214.
7. BUEL, J., Choice-Point "Expectancy" in the Linear Maze. *Psychol. Bull.*, 1932, **29**, 543.
7a. BUEL, J., The Linear Maze: I. "Choice-Point Expectancy", "Correctness", and the Goal Gradient. *J. Comp. Psychol.*, 1934, **17**, 185–199.
7b. BUEL, J., and BALLACHEY, E. L., Choice-Point Expectancy in the Maze Running of the Rat. *J. Genet. Psychol.*, 1934, **45**, 145–168.
8. CARR, H., The Distribution and Elimination of Errors in the Maze. *J. Anim. Behav.*, 1917, **7**, 145–159.
9. CARR, H., Maze Studies with the White Rat. I. Normal Animals; II. Blind Animals; III. Anosmic Animals. *J. Anim. Behav.*, 1917, **7**, 259–306.
10. CARR, H., and KOCH, H., The Influence of Extraneous Controls in the Learning Process. *Psychol. Rev.*, 1919, **26**, 287–293.
11. CARR, H., and WATSON, J. B., Orientation in the White Rat. *J. Comp. Neur. & Psychol.*, 1908, **18**, 27–44.
12. CLEMENTS, F. E., The Effect of Time on Distance Discrimination in the Albino Rat. *J. Comp. Psychol.*, 1928, **8**, 317–324.
13. COREY, S. M., Sex Differences in Maze Learning by White Rats. *J. Comp. Psychol.*, 1930, **10**, 333–338.
14. CROZIER, W. J., and PINCUS, G., On the Geotropic Orientation of Young Mammals. *J. Gen. Physiol.*, 1928, **11**, 789–802.
15. CROZIER, W. J., The Study of Living Organisms. In *The Foundations of Experimental Psychology*, ed. by C. Murchison. Worcester, Mass.: Clark Univ. Press; London: Oxford Univ. Press, 1929, pp. 45–127.
16. DASHIELL, J. F., Some Transfer Factors in Maze Learning by the White Rat. *Psychobiol.*, 1920, **2**, 329–350.
17. DASHIELL, J. F., Direction Orientation in Maze Running by the White Rat. *Comp. Psychol. Monog.*, 1930, VII, No. 2.
18. DASHIELL, J. F., and BAYROFF, A. G., A Forward Going Tendency in Maze Running. *J. Comp. Psychol.*, 1931, **12**, 77–95.
19. DASHIELL, J. F., and HELMS, H. A., Learning in White Rats of an Inclined Plane Maze. *J. Comp. Psychol.*, 1925, **5**, 397–406.
20. DECAMP, J. E., Relative Distance as a Factor in the White Rat's Selection of a Path. *Psychobiol.*, 1920, **2**, 245–253.
21. DENNIS, W., The Sensory Control of the White Rat in the Maze Habit. *J. Genet. Psychol.*, 1929, **36**, 59–90.
22. DENNIS, W., A Study of Learning in the White Rat. *J. Genet. Psychol.*, 1930, **37**, 294–308.
23. DENNIS, W., Multiple Visual Discrimination in the Block Elevated Maze. *J. Comp. Psychol.*, 1932, **13**, 391–396.
24. ELLIOTT, M. H., The Effect of Change of Reward on the Maze Performance of Rats. *Univ. Calif. Publ. Psychol.*, 1928, **4**, 19–30.
25. ELLIOTT, M. H., The Effect of Appropriateness of Reward and of Com-

plex Incentives on the Maze Performance of Rats. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 91–98.

26. Elliott, M. H., The Effect of Change of "Drive" on Maze Performance. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 185–188.
27. Gengerelli, J. A., The Principle of Maxima and Minima in Animal Learning. *J. Comp. Psychol.*, 1931, **11**, 193–236.
28. Hamill, R., Sequence of Turns vs. Distances as Essential Pattern Elements in the Maze Problem. *J. Comp. Psychol.*, 1931, **11**, 367–382.
29. Hamilton, E. L., The Effect of Delayed Incentive on the Hunger Drive in the White Rat. *Genet. Psychol. Monog.*, 1929, **5**, 137–166.
30. Haney, G. W., The Effect of Familiarity on the Maze Performance of Albino Rats. *Univ. Calif. Publ. Psychol.*, 1931, **4**, 319–333.
31. Helson, H., Insight in the White Rat. *J. Exper. Psychol.*, 1927, **10**, 379–396.
32. Heron, W. T., Habit Formation and Higher Mental Processes in the Rat. *Psychol. Bull.*, 1932, **29**, 461–492.
33. Higginson, G. D., Visual Perception in the White Rat. *J. Exper. Psychol.*, 1926, **9**, 337–348.
34. Higginson, G. D., The After-Effects of Certain Emotional Situations upon Maze Learning Among White Rats. *J. Comp. Psychol.*, 1930, **10**, 1–10.
35. Honzik, C. H., Cerebral Control in the Maze Learning of Rats. *Psychol. Bull.*, 1932, **29**, 542–543, and *J. Comp. Psychol.*, 1933, **15**, 95–132.
36. Hsiao, H. H., An Experimental Study of the Rat's Insight Within a Spatial Complex. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 57–70.
37. Hubbert, H. B., Elimination of Errors in the Maze. *J. Anim. Behav.*, 1915, **5**, 66–72.
38. Hubbert, H. B., and Lashley, K. S., Retroactive Association and the Elimination of Errors in the Maze. *J. Anim. Behav.*, 1917, **7**, 130–138.
39. Hull, C. L., The Goal Gradient Hypothesis and Maze Learning. *Psychol. Rev.*, 1932, **39**, 25–44.
40. Hunter, W. S., The Sensory Control of the Maze Habit in the White Rat. *Ped. Sem. and J. Genet. Psychol.*, 1929, **36**, 505–536.
41. Husband, R. W., A Comparison of Human Adults and White Rats in Maze Learning. *J. Comp. Psychol.*, 1929, **9**, 361–377.
42. Jackson, T. A., General Factors in Transfer of Training in the White Rat. *Genet. Psychol. Monog.*, 1932, **11**, No. 1.
43. Krechevsky, I., "Hypothesis" vs. "Chance" in the Pre-solution Period in Sensory Discrimination-Learning. *Univ. Calif. Publ. Psychol.*, 1932, **6**, 27–44.
44. Krechevsky, I., The Genesis of "Hypothesis" in Rats. *Univ. Calif. Publ. Psychol.*, 1932, **6**, 45–64.
45. Krechevsky, I., Heredity Nature of "Hypotheses". *J. Comp. Psychol.*, 1933, **16**, 99–116.
46. Krechevsky, I., "Hypotheses" in Rats. *Psychol. Rev.*, 1932, **39**, 516–532.
47. Lashley, K. S., *Brain Mechanisms and Intelligence.* Chicago, Ill.: Univ. Chicago Press, 1929, 137–138.
48. Lashley, K. S., A Causal Factor in the Relation of the Distribution of Practice to the Rate of Learning. *J. Anim. Behav.*, 1917, **7**, 139–142.

49. LEUBA, J. H., and FAIN, V., Note on Orientation in the White Rat. *J. Comp. Psychol.*, 1929, **9**, 239–244.
50. LEWIN, K., Environmental Forces in Child Behavior and Development. In *A Handbook of Child Psychology*, ed. by C. Murchison. Worcester, Mass.: Clark Univ. Press; London: Oxford Univ. Press, 1931, 94–125.
51. LIGGETT, J. R., The Unit Maze: A Study in Maze Method. *J. Genet. Psychol.*, 1930, **37**, 163–175.
52. LIGGETT, J. R., and LIGGETT, M. W., On the Modifications of the Learning Rate of the White Rat Following the Removal of the Olfactory Lobes. *Ped. Sem.*, 1927, **34**, 525–536.
53. LIU, S. Y., The Relation of Age to the Learning Ability of the White Rat. *J. Comp. Psychol.*, 1928, **8**, 75–85.
54. MACFARLANE, D. A., The Rôle of Kinesthesis in Maze Learning. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 277–305.
55. MAIER, N. R. F., Reasoning in White Rats. *Comp. Psychol. Monog.*, 1929, **6**, No. 29.
56. MILES, W. R., The Comparative Learning of Rats on Elevated and Alley Mazes of the Same Pattern. *J. Comp. Psychol.*, 1930, **10**, 237–261.
57. PATRICK, J. R., The Effect of Emotional Stimuli on the Activity Level of the White Rat. *J. Comp. Psychol.*, 1930, **10**, 295–307.
58. PATRICK, J. R., and ANDERSON, A. C., The Effect of Incidental Stimuli on Maze Learning with the White Rat. *J. Comp. Psychol.*, 1930, **10**, 295–307.
59. PETERSON, J., The Effect of Length of Blind Alleys on Maze Learning: An Experiment on Twenty-four White Rats. *Behav. Monog.*, 1917, **3**, No. 15.
60. PETERSON, J., Frequency and Recency Factors in Learning by White Rats. *J. Anim. Behav.*, 1917, **7**, 338–364.
61. RICHARDSON, F., A Study of Sensory Control in the Rat. *Psychol. Rev. Monog. Sup.*, 1910, **12**, No. 48. Pp. 124.
62. ROBINSON, E. W., and WEVER, E. G., Visual Distance Perception in the White Rat. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 233–239.
63. RUCH, F. L., Goal Direction Orientation and Goal Gradient as Factors in Maze Learning. *Psychol. Bull.*, 1932, **29**, 646–647.
64. RUCH, T. C., Preliminary Study of the Ability of the Albino Rat to Discriminate Inclined Planes. *J. Comp. Psychol.*, 1927, **7**, 405–423.
65. RUCH, T. C., The Discrimination Ability of Albino Rats Measured by a Triple-Unit Inclined Plane Discrimination Apparatus. *J. Comp. Psychol.*, 1930, **10**, 11–34.
66. SCHNIERLA, T. C., Learning and Orientation in Ants. *Comp. Psychol. Monog.*, 1929, **6**, No. 30.
67. SHARP, W. L., Disintegrative Effects of Continuous Running and Removal of Food Incentive upon a Maze Habit of Albino Rats. *J. Comp. Psychol.*, 1929, **9**, 405–423.
68. SHIRLEY, M., Studies in Activity. IV. The Relation of Activity to Maze Learning and to Brain Weight. *J. Comp. Psychol.*, 1928, **8**, 187–195.
69. SLONAKER, J., The Normal Activity of the Albino Rat from Birth to Natural Death, Its Rate of Growth and the Duration of Life. *J. Anim. Behav.*, 1912, **2**, 20–42.

70. SPENCE, K. W., The Order of Eliminating Blinds in Maze Learning by the Rat. *J. Comp. Psychol.*, 1932, **14**, 9–27.
71. TOLMAN, E. C., *Purposive Behavior in Animals and Men.* New York: Century, 1932.
72. TOLMAN, E. C., and HONZIK, C. H., "Insight" in Rats. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 215–232.
73. TOLMAN, E. C., and HONZIK, C. H., Degrees of Hunger, Reward, and Non-Reward, and Maze Learning in Rats. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 241–256.
74. TOLMAN, E. C., and HONZIK, C. H., Introduction and Removal of Reward, and Maze Performance in Rats. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 257–275.
75. TOLMAN, E. C., HONZIK, C. H., and ROBINSON, E. W., The Effect of Degrees of Hunger upon the Order of Elimination of Long and Short Blinds. *Univ. Calif. Publ. Psychol.*, 1930, **4**, 189–202.
76. TOLMAN, E. C., and SAMS, C. F., Time Discrimination in White Rats. *J. Comp. Psychol.*, 1925, **5**, 255–263.
77. TRYON, R. C., The Genetics of Learning Ability in Rats—A Preliminary Report. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 71–80.
78. TRYON, R. C., Studies in Individual Differences in Maze Ability. I. The Measurement of the Reliability of Individual Differences. *J. Comp. Psychol.*, 1930, **11**, 145–170.
79. TRYON, R. C., Studies in Individual Differences in Maze Ability. II. The Determination of Individual Differences by Age, Weight, Sex and Pigmentation. *J. Comp. Psychol.*, 1931, **12**, 1–22.
80. TRYON, R. C., Studies in Individual Differences in Maze Ability. V. Luminosity and Visual Acuity as Systematic Causes of Individual Differences, and an Hypothesis of Maze Ability. *J. Comp. Psychol.*, 1931, **12**, 401–420.
81. TSAI, L. S., The Cul-de-Sac Phenomena. *J. Comp. Psychol.*, 1931, **12**, 393–400.
82. TSAI, L. S., The Laws of Minimum Effort and Maximum Satisfaction in Animal Behavior. *Monog. Nat. Res. Instit. Psychol.* (Peiping, China), 1932, No. 1. (*Psychol. Abst.*, 1932, **6**, 4329.)
83. ULRICH, J. L., The Distribution of Effort in Learning in the White Rat. *Behav. Monog.*, 1913–1915, **2**, No. 5.
84. ULRICH, J. L., Integration of Movements in Learning in the Albino Rat. A Study of the Adjustment of an Organism to an Environment. *J. Comp. Psychol.*, 1921, **1**, 1–95, 155–199, 221–286.
85. UTSURIKAWA, N., Temperamental Differences between Outbred and Inbred Strains of the Albino Rat. *J. Anim. Behav.*, 1917, **7**, 111–129.
86. VALENTINE, R., The Effect of Punishment for Errors on the Maze Learning of Rats. *J. Comp. Psychol.*, 1930, **10**, 35–53.
87. VICARI, E. M., Mode of Inheritance of Reaction Time and Degrees of Learning in Mice. *J. Exper. Zōol.*, 1929, **54**, 31–88.
88. VINCENT, S. B., The Function of the Vibrissae in the Behavior of the White Rat. *Behav. Monog.*, 1912, **1**, No. 5.
89. VINCENT, S. B., The White Rat and the Maze Problem. I. Introduction of a Visual Control. *J. Anim. Behav.*, 1915, **5**, 1–24.

90. VINCENT, S. B., The White Rat and the Maze Problem. II. An Introduction of an Olfactory Control. *J. Anim. Behav.*, 1915, **5**, 140–157.
91. VINCENT, S. B., The White Rat and the Maze Problem. III. Introduction of a Tactual Control. *J. Anim. Behav.*, 1915, **5**, 175–184.
92. VINCENT, S. B., The White Rat and the Maze Problem. IV. The Number and Distribution of Errors. *J. Anim. Behav.*, 1915, **5**, 367–374.
93. WARDEN, C. J., The Value of the Preliminary Feeding in the Problem Box. *J. Comp. Psychol.*, 1925, **5**, 365–372.
94. WARDEN, C. J., A Symmetrical Linear Maze for Use in the Analysis of Animal Serial Learning. *J. Genet. Psychol.*, 1929, **36**, 177–178.
95. WARREN, C. J., and CUMMINGS, S. B., Primacy and Recency Factors in Animal Motor Learning. *J. Genet. Psychol.*, 1929, **36**, 240–256.
96. WARDEN, C. J., and HAMILTON, E. L., The Effect of Variation in Length of Maze Pattern upon the Rate of Fixation in the White Rat. *J. Genet. Psychol.*, 1929, **36**, 229–239.
97. WARDEN, C. J., and HAAS, E. L., The Effect of Short Intervals of Delay upon Speed of Maze Learning. *J. Comp. Psychol.*, 1927, **7**, 107–127.
98. WARNER, L. H., and WARDEN, C. J., The Development of a Standardized Animal Maze. *Arch. of Psychol.*, 1927, **15**, No. 93.
99. WASHBURN, M. F., Hunger and Speed of Running as Factors in Maze Learning in Mice. *J. Comp. Psychol.*, 1926, **6**, 181–187.
100. WASHBURN, M. F., COLLENS, E. L., and UPJOHN, E., The Relation to Hunger and Activity Drives of the Factor of Habituation to the Maze. *J. Comp. Psychol.*, 1931, **12**, 421–427.
101. WASHBURN, M. F., and EBERSBACH, R., The Effects of the Direction of the Initial Pathways on the Orientation of White Mice in a Maze. *Amer. J. Psychol.*, 1930, **42**, 413–414.
102. WATSON, J. B., The Effect of Delay in Feeding upon Learning. *Psychobiol.*, 1917, **1**, 51–60.
103. WATSON, J. B., Kinesthetic and Organic Sensations: Their Rôle in the Reactions of the White Rat. *Psychol. Rev. Monog.*, 1907, **8**, No. 2.
104. WHITE, A. E., and TOLMAN, E. C., A Note of the Elimination of Short and Long Blind Alleys. *J. Comp. Psychol.*, 1923, **3**, 327–331.
105. WILLIAMS, K. A., The Reward Value of a Conditioned Stimulus. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 31–55.
106. YOSHIOKA, J. G., A Note on a Right or Left Going Position Habit with Rats. *J. Comp. Psychol.*, 1928, **8**, 429–433.
107. YOSHIOKA, J. G., A Preliminary Study in the Discrimination of Maze Patterns by the Rat. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 1–18.
108. YOSHIOKA, J. G., A Further Study in Discrimination of Maze Patterns by the White Rat. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 135–153.
109. YOSHIOKA, J. G., Weber's Law in the Discrimination of Maze Distance by the White Rat. *Univ. Calif. Publ. Psychol.*, 1929, **4**, 155–184.
110. YOSHIOKA, J. G., A Further Note on a Position Habit in Rats. *Univ. Calif. Publ. Psychol.*, 1930, **10**, 309–315.
111. YOSHIOKA, J. G., Direction as a Factor in Maze Solution in Rats. *J. Genet. Psychol.*, 1930, **38**, 307–320.

BOOK REVIEWS

SEASHORE, C. E., ED. University of Iowa Studies, Studies in the Psychology of Music, Vol. 1, *The Vibrato*. Iowa City, Iowa: University of Iowa, 1932. Pp. 382.

The reviewer firmly believes that the work of the Iowa psychologists on the vibrato constitutes not only the most significant research project of that laboratory, but also the most important contribution to aesthetics psychologists have ever made. Dean Seashore is to be congratulated for initiating this work.

The volume under discussion has been written by a number of the experimenters who have contributed most to our knowledge of the vibrato. Professor Seashore, as editor, is responsible for a brief introduction. Of special interest is his promise to make available a small popular text on the vibrato and a number of phonograph records which will present scales for the measurement of attainment in the control of the vibrato.

The chapter entitled "The Vibrato in Artistic Voices"—almost a third of the volume—is by Professor Metfessel who is continuing the study of the vibrato in his own laboratory at the University of Southern California. To the reviewer the most important of the findings concerning voice vibrato would appear to be the fact that "ninety-five per cent of artistic tones, long and short, gliding and steady, high and low, pianissimo and fortissimo, register vibrato". The artistic vibrato, as defined by Metfessel, is an oscillation of the voice which varies "in rate from 5.5 to 8.5 pulses per second, with an average of 7". The oscillation extends "from a tenth to over a whole step, averaging a half step". There are also timbre and intensity changes. "One out of every five adults possesses a vibrato involuntarily. Nine out of ten who choose voice as a vocation or avocation possess some kind of vibrato." "A trill is distinguished from a vocal vibrato mainly because of extent, trills varying from three-quarters to two whole steps. A tremolo is a disagreeable vibrato caused by any factor which interferes with the saliency of the vibrato pitch, or the evenness of the vibrato pulsation." When musicians speak of the vibrato as a bad habit they probably mean the tremolo of Metfessel's terminology. A physical

description of the conditions under which the vibrato is produced does not obviate the necessity for psychological descriptions. In fact, Metfessel has discovered a type of psychological fusion which he has termed 'sonance'. "In the vibrato the pitches which unite into a unique auditory impression are sounded one rapidly after the other, and here the fusion is a 'successive' one."

The next two chapters are by Professor Tiffin. The first contains descriptions of the strobophotograph camera and the vacuum tube voltmeter. The second is entitled "The Role of Pitch and Intensity in the Vocal Vibrato of Students and Artists". Since Tiffin's study of the pitch and rate factors occurred later than did the major portion of Metfessel's work, slightly improved methods were employed. However, the data of the two studies checked reasonably well. Tiffin has concluded that "it is probably the fluctuation of pitch, not intensity, which is most significant in producing the vibrato effect in the normal singing voice".

Tiffin has been most careful to state that he has been studying artist performances *of the present day,* and that a similar study fifty years from now might yield different results. The reviewer was pleased to read this statement as he had felt that Seashore and to some extent certain of his earlier students have fallen, perhaps, into the habit of assuming absolute standards, that is, of accepting present art practice as the absolute ideal. In fact at one point in the monograph there appears the following: "Unless the voice vibrato has those elements in accordance with the artists, it is not fully artistic." Surely absolute standards must be implied; otherwise this statement is redundant—unless the voice vibrato resembles that of artists it does not resemble it. That the differentiation between the tremolo and the vibrato should be made with great caution is demonstrated by Tiffin's discovery that the vibrato of two eminent artists would have been labelled inartistic by the earlier workers.

Professor A. H. Wagner, the author of the following section, describes his successful attempts to teach vocalists to perform the vibrato and to modify it to fit certain 'approved' patterns.

H. G. Seashore reports the most recent work on the hearing of pitch and intensity in vibrato. "The data indicate that listeners do not hear the actual physical changing of pitch and intensity, but only a fractional part thereof—one-fourth to one-half." "There are wide differences in ability of observers to detect differences in

pulsation in the pitch vibrato, the average value, in the region of the average musical vibrato extent, being about .15 of a step, the range extending from .05 to about .40 of a step."

There follow several fairly short sections. Pioneer work on the timbre vibrato is being conducted by D. A. Rothschild; treatment is by the Henrici harmonic analyzer. F. E. Linder and R. S. Miller report on their analyses of non-sustained intonations. The vibrato was found to be present. E. Easley finds that "the average vibrato in opera songs sung by opera singers is significantly wider and faster than the vibrato in concert songs sung by the same opera singers" (when emotional excitement is presumed to be less). M. Hattwick finds that the vibrato is used by certain wind instrument artists but not by others. M. T. Hollinshead and S. N. Reger present data on the string instrument vibrato. Its rate is approximately the same as that of the vocal vibrato, but it has an extent only half as great. The monograph ends with an excellent summary by Tiffin and H. G. Seashore of the "Established Facts in Experimental Studies on the Vibrato up to 1932". There is a bibliography of 144 titles.

PAUL R. FARNSWORTH.

Stanford University.

STEWART, GEORGE WALTER. *Introductory Acoustics.* New York: D. Van Nostrand Co., 1932. Pp. xi+200.

As the author tells us in the preface, this book was written with particular regard for the requirements of students specializing in music, speech, and psychology. It deals with the subject of acoustics in an elementary way, with minimum requirements of physical and mathematical training.

The first 6 chapters, together with Chapters 12 and 13, deal with the basic principles of physical acoustics, and include discussions of the nature of sound waves, their reflection, absorption, diffraction, and transmission, and the phenomena of resonance. Of particular note is the discussion of the rôle of phase in reflection. In Chapter 2, and again briefly in Chapter 12, the acoustics of buildings is treated.

Chapters 7, 8, 9, 14, and 15 deal with the application of acoustical principles to music and speech. Among the topics treated are the nature of musical sounds, the formation of scales, the character of speech sounds, and the action of musical instruments.

Chapters 10 and 11 deal with the psychology of hearing, and include discussions of thresholds, masking, asymmetry in the action of the ear, and binaural phenomena.

The discussion of many topics is necessarily brief, but the treatment of basic principles is sufficient to give the student a substantial and precise knowledge of the field. The topics of reflection and resonance are more thoroughly dealt with here than in many of the advanced texts on acoustics.

Except for a somewhat greater emphasis on binaural effects, the treatment of psychological topics is similar to that of other texts on sound written by physicists and engineers. An unusual feature of the discussion of loudness is the distinction of Weber's and Fechner's laws and the correct statement of each. But the customary confusion as regards "sensation units" and "decibels" prevails (pp. 128–130). This matter of intensity and loudness will remain obscure in the sound engineering literature until care is exercised to keep physical and psychological quantities distinct. The decibel may be defined and used as a measure of physical intensity, irrespective of any relation to just-noticeable differences, and thus need not be involved in the attempts, so far unsuccessful, to work out a "unit" of loudness.

A less important confusion arises from the use of the term "binaural beats" (p. 148). The phenomenon in question is psychologically distinct from that of beats, and should be called by another name, such as "binaural phase effect". The author indeed uses the last expression on page 147.

A third question of terminology arises from the use of the expression "mean temperament" for what is commonly known as "equal temperament". The author's use is logical, since the scale consists theoretically of a series in which each tone is a geometrical mean between its neighbors, but such use is likely to lead to confusion with the older mean-tone temperament which is based upon a different principle.

The author on page 133 seems to attribute to Fletcher the work on the minimum time required for tone perception, probably because the latter in the work cited did not give credit to R. Bode (*Psychol. Stud.*, 1907) from whom the data were taken. (Elsewhere [*Bell Tech. Jour.*, 1925], it might be added, Fletcher made the proper reference.)

The above criticisms should not be over-emphasized. In both treatment and scope the book is well adapted to its purpose and represents a very valuable contribution to the literature on acoustics.

E. G. WEVER.

Princeton Psychological Laboratory.

STERN, GUSTAF. *Meaning and Change of Meaning, with Special Reference to the English Language.* Göteborg, 1931. Pp. 456.

Mr. Stern has set himself the task of systematizing the scattered and piecemeal investigations carried on in semasiology and in the related fields of linguistic psychology. His volume can be conveniently divided into two sections. In the first six chapters he attempts to build a theoretical framework for the ensuing classification of sense-changes, discussing boldly such esoteric problems as the functions of speech, the psychic processes involved in the production and comprehension of speech, thinking in relation to the word, phrase, referent, and meaning. The procedure is largely a critical sifting of the vast body of fragmentary literature bearing on the psychological problems involved in meaning.

If this first section is nebulous and weak, the blame cannot be attached to the author, for linguistic psychology offers no pivotal or compelling concepts for its phenomena; the material available consists of a few significant investigations buried in a mass of speculations concerning the "nature" of language. Although Mr. Stern places a great deal of stress upon the brilliant formulations of Henry Head, whose work on aphasia has become a classic, he follows other linguists in overlooking the caution offered by Head, who asserted that his classification of linguistic activity was a pragmatic scaffolding erected for the purpose of dealing with aphasic problems, that it was not to be considered a general analysis of the normal acts of speech. Mr. Stern might have saved himself much painstaking labor if he had extended Head's caution to the greater part of his psychological material.

The remaining eight chapters, however, present a valuable contribution to semasiological literature. Changes of meaning are analyzed genetically into seven major types.

1. Substitution (caused by cultural changes): *ship* contains meanings it did not have before steamships and airships were invented.

2. Analogy: the adverb *fast* shows a continuous development from "immovably" to "rapidly", and the latter meaning was, by

analogy, extended to the adjective *fast,* which originally meant only "immovable".

3. Shortening: *private,* as a shortened form of the compound expression *private soldier,* has undergone a sense-change.

4. Nomination (an intentional transfer of a name from one referent to another): figures of speech belong to this category.

5. Regular transfer (an unintentional transfer): pages of a book are called *leaves,* for their flat, thin shape suggests the leaves of a tree.

6. Permutation (a shift of meaning assumed by a word in a phrase to include a newly emphasized element of a total situation): *beads,* in *he counts his beads,* originally meant "prayers", the phrase referring to the practice of counting prayers by means of the balls on a rosary; the term then came to refer to the balls themselves.

7. Adequation (an adaptation of the meaning of a word to a newly apprehended element of the referent): *horn* originally referred to an animal's horn, which could be used for producing sounds; the notion of this purpose was later apprehended as the chief characteristic of the referent, and *horn* came to be applied to a similar sound-producing instrument made from other materials.

Although Mr. Stern analyzes his classes into many minor and sub-minor divisions, he is fully aware that his lines of demarcation do not form an absolute and inflexible system. Even the major classes may overlap: it is often difficult to posit whether a sense-change is to be classed as a nomination (intentional transfer) or as a regular (unintentional) transfer. Some sense-changes, furthermore, must be included in two or even three of the rubrics. But, in spite of minor criticisms concerning details that one might offer, Mr. Stern's system presents a working classification of sense-changes superior to any yet encountered.

STANLEY NEWMAN.

Yale University.

PORTEUS, S. D. *The Maze Test and Mental Differences.* Vineland, N. J.: Smith Printing and Publishing House. 1933. Pp. 212.

Chapters I to III constitute an introductory section in which the author discusses the nature of intelligence and mental deficiency, and methods of mental diagnosis.

In Chapters IV to VII are summarized and reviewed "all important studies in which the Maze Test has been used", including

those designed to measure its validity. The data are interpreted as demonstrating: first, that for children of defective levels of intelligence the Maze has a closer relation to social sufficiency than the Binet; second, that cultural and environmental handicaps are of small importance in determining the Maze test results; and third, because of the second, that the tests are useful for the study of racial differences.

The use of the Maze tests in the study of racial differences in Hawaii is described at some length, for the author is of the opinion that all the major objections to racial comparisons are inapplicable there. He interprets the data as establishing racial differences in native ability.

A revision of the Maze tests is presented in Chapter VIII and Appendices I and II. A table of Test Quotients is supplied in which have been incorporated various corrections designed to bring the average Test Quotients for each age group to about 100. The author reports having found evidence of improved standardization in the use of the revision on 1,000 Honolulu school children.

The reviewer has the impression that both the standardization of the tests and the interpretation of the results of their use have suffered from a lack of adequate statistical treatment. Nevertheless a substantial validation of the tests is apparent in the data. Users of the tests will welcome the benefits of the author's experience in the revision.

J. W. TILTON.

Yale University.

CUTSFORTH, THOMAS D. *The Blind in School and Society. A Psychological Study.* New York: D. Appleton and Company, 1933. Pp. xix+263.

The cliché to be used in describing this book is "challenging". That is the word we use at present when a writer does not accept the *status quo,* when he is very critical of our present aims and achievements, and points loftily to other aims and a far better world somewhere in the dim future. The author does not like the present educational system for the blind and he lets the reader know this almost continuously throughout the book. There is not any one particular thing that is wrong. All of it is wrong. With sharp critical comments he pokes into every aspect of the education of the blind. The blind are taught words rather than reality. The

attitude of the teachers and the seeing in general creates all kinds of emotional complications for the blind. Pernicious sex behavior is due to institutional regulations. The blind are crippled in their aesthetic life by the present educational ideals. The institutional life of the blind gives rise to all sorts of personality problems.

All of the author's criticisms may be true, although there is little evidence for some of them, and many of his generalizations are far too sweeping. The trouble lies just there. The book will create an antagonistic feeling among educators of the blind and fail to have that influence which it deserves to have because of the many important questions which it raises. The plea for more reality and less verbalism in the education of the blind is important, and is an issue that teachers of the blind should face frankly. It is of no value to teach the blind to write and speak as if they could see, and pretend to appreciate those visual aspects of experience which are prized by seeing people. Very trenchant in this connection are the author's comments on the education of Helen Keller. Her writing is false and hypocritical, dealing as it does so largely with visual concepts that can have little or no meaning for her. The too-early teaching of Braille leads to all sorts of emotional difficulties which frequently prejudice the child against all reading. This seems reasonable, but the author presents no objective evidence. Indeed, that is one trouble throughout the whole book. The evidence upon which the author bases his opinions is seldom presented, and seems non-existent in many cases. Of most importance is the author's point of view and his own philosophy of life and particular type of psychology. Little attention is paid to the psychological work of previous writers. Absolutely no mention of Hayes' psychological tests of blind children is made. Evidently our author does not like tests. But he likes case studies. There are four very interesting ones. The case of general retardation is a very unusual one. The boy did not enter a blind school until the age of twenty-four. The case studies of the two blind students in college are very well done. The contrast between the two personalities is well brought out, but whether blindness was the primary factor in leading to the lack of adjustment of one of the students is very questionable. Many seeing college students also fail to make adequate adjustments. The fourth case study is that of Mr. R., the blind mendicant. Our author tells this story with such gusto, that one is almost driven to conclude that under present conditions a blind

man can only "resist disintegration" and "maintain his personal independence" by becoming a blind beggar.

I hope all those interested in the blind will read this book. It raises many problems that call for thought and discussion. The psychologist will see many areas in this field which are badly in need of careful experimentation and research.

R. PINTNER.

Teachers College, Columbia University.

TWITMEYER, EDWIN BURKET, and NATHANSON, YALE SAMUEL. *Correction of Defective Speech.* Philadelphia: P. Blakiston's Son and Company, Inc., 1932. Pp. xviii+413.

The subtitle to *Correction of Defective Speech* is "a complete manual of psycho-physiological techniques for the treatment and correction of the defects of speech". In the preface, the authors assert that the volume is presented "in response to the existing need for suitable material that shall offer a technique for the correction of all types of speech mutilations from the faulty articulation of the persistent 'baby talker', to cases of profound stammering and stuttering". Thus the authors indicate they understand what kind of manual is urgently needed in the field of speech correction.

The book they produce seems to have eluded their purpose. It contains a description of the psycho-physiological approach; a section on techniques and speech exercises with very little attention to techniques; a brief description of the case record and progress charts; and two addenda.

In the psycho-physiological approach, the authors advocate a synthesis of the bio-chemical, physiological, psychological, and pedagogical factors—an approach which does not appear essentially new nor difficult except that it involves the determining of imaginal types and the teaching of the "correct kinaesthetic and muscular imagery" (p. 9)—an essential phase of the approach for which no adequate techniques are presented.

In the various examinations advocated, the reviewer doubts the clinical value of the analysis of saliva, urine, alveolar carbon dioxide, and hemato-respiratory processes as part of the bio-chemical examination, until more conclusive work has been produced from the laboratories of Trumper, Starr, Stratton, and others. This work should be presented to speech correctionists for their consideration and critical evaluation. Much more such experimentation should

be encouraged if we are to improve clinical methods; however, at the present stage, no one of the experiments contains conclusive findings upon which to base a method of treatment for specific speech defects. The authors have presented no methods in this "manual" for use of these analyses if they have been made for diagnosis of their own clinical cases.

In describing the approach, emphasis is placed on the use of 'frequency words', but very many infrequently used words are introduced into the contents of the exercises presented here.

On p. 14, the authors explain progressive sound grouping and advocate the use of a formula to assure a completeness which would account for, "not only every sound in the English language, but a method which with minor adaptations would be applicable to any of the languages of the Indo-European groups". This should be a valuable formula, but unfortunately no explanation is made of what the symbols in the formula represent!

Part II, the section on corrective material and technique, consists of a collection of breathing and articulation exercises. Though the authors doubtless apply the drills with proper consideration for individual differences (they state this caution in the preface), the fact that they stress "passing from the known to the unknown" and "the importance of learning each sound and mastering each step before going to the next" (p. 363), makes the reader question the adaptability of this system. No special therapy is presented for special cases and the reader concludes that the "deaf", the "cleft palate", "negativism", and "foreign accent" are all treated alike, and drilled through the 320 pages of exercises regardless of the mildness or severity of their defects.

This book contains no bibliography in its main substance (two references are given by Nathanson in the first addendum); neither is there an index. There is no reference to the valuable work of Fletcher, Travis, Dunlap, and others. The authors present their material as if they were pioneers in the field and conclude with the statement that they have presented a "complete system for the correction of the defects of speech".

The book contains an interesting analysis of the breaking of habits, based on a theory similar to Dunlap's gamma-hypothesis; the case record is emphasized and a series of progress charts are presented. There is an interesting analysis of sound in the "curve of articulation" (p. 11).

It is quite obvious that the book so urgently needed in the field of speech corrections and so adequately described in the preface of this volume has not been produced. The present book may have value in the hands of the authors, but it is wholly inadequate for the use by others in giving examinations, in diagnosing cases, in description of method of using speech material and techniques, in method of correcting the particular speech difficulties referred to in the preface, and in techniques for "obtaining the correct kinaesthetic and muscular imagery fundamental to the psycho-physiological approach".

THELMA A. DREIS.

Yale University.

SEGEL, DAVID. *Differential Diagnosis of Ability in School Children.* Baltimore: Warwick and York, Inc., 1934. Pp. 86.

Precise measurement of individual weaknesses and abilities in school children can be accomplished by means of modern tests only when the appropriate statistical techniques are used to interpret test results. This book presents a concise description of methods directly useful in guidance. In orderly fashion the author presents evidence that traits involved in school abilities are differentiable; he shows the need for differential diagnosis, and outlines procedures by which the efficiency of tests may be evaluated. He then describes two methods used to make a differential diagnosis. In the last chapter, he discusses an array of tests which are at present available, and probably more than ordinarily useful for the purpose.

Segel does not merely present a point of view; he furnishes a considerable body of information, and refers to abundant source material. Since the statistical methods for interpreting differences between individual test scores have been much neglected in practice, a definite service is rendered by making them available in elementary form. For those who wish the details of quantitative logic underlying the formulas, references are given to the proper sources of such additional information. Whether the worker's aim is to discover weaknesses in order to prescribe remedial training, or to discover special talents which can profitably be encouraged, it is necessary first to make a diagnosis. This book tells how to use modern tests to discover pertinent facts about the child.

The author has accomplished the difficult task of describing technical research methods in simple and elementary form. For the most part, the writing is clear and effective. Teachers and students in

mental test classes will find the monograph very useful; although it will not be understood completely by those who have had no training in statistics, such readers will grasp the general argument. Since the book deals with the application of techniques, not with the derivations, it can be read with profit by the school teacher who has had a single course in educational statistics. Probably the intelligent use of statistical procedures in the modern school system will be most encouraged by this type of elementary presentation of methods bearing upon specific problems. Not only does this book satisfy a specific need in guidance, but it deserves a place in a general program for keeping the teacher well informed.

H. D. CARTER.

University of California Institute of Child Welfare.

NOTES AND NEWS

THE SECRETARY of the American Psychological Association, Professor Donald G. Paterson, reports that the mail ballot recently conducted in regard to the place of the Forty-Third Annual Meeting and in regard to time of meeting subsequent to 1935 resulted as follows: 404 to accept the invitation from the University of Colorado, 572 to accept the invitation from the University of Michigan; 321 in favor of late December meetings, 653 in favor of early September meetings. In accordance with the results of this mail ballot the next Annual Meeting will be held at the University of Michigan, Ann Arbor, Michigan, on September 4, 5, 6, and 7, 1935, and the meetings subsequent to 1935 will be held as usual, sometime during the first two weeks of September.

THE twelfth annual meeting of the American Orthopsychiatric Association will be held at the Pennsylvania Hotel in New York, N. Y., February 21, 22, 23, 1935. Dr. George S. Stevenson, President. Office of the Secretary, 50 West 50th Street, New York, N. Y.

THE tenth annual meeting of the Midwestern Psychological Association will be held at the University of Kansas, Lawrence, on May 10 and 11, 1935. The officers are: President, John A. McGeoch, University of Missouri; Secretary-Treasurer, Arthur G. Bills, University of Chicago.

SECTION I (Psychology) of the American Association for the Advancement of Science met in Pittsburgh from Thursday, December 27, to Saturday, December 29. There were six sessions devoted to experimental and theoretical papers. A special feature of the program was a symposium on theories of learning in which papers were read by Professors Mandel Sherman, R. M. Ogden, J. F. Dashiell, and C. L. Hull. At a joint banquet with Section Q (Education) Professor W. R. Miles, retiring vice-president of Section I, read his vice-presidential address on "Training, Practice and Mental Longevity", and Professor Walter F. Dearborn, retiring vice-president of Section Q, read his vice-presidential address on "The Mental and Physical Growth of Public School Children". Professor Joseph Peterson was elected vice-president of Section I for 1935 and Professor J. F. Dashiell was elected to the section committee. Professor John E. Anderson is the retiring vice-president for 1935, and Professor John A. McGeoch is secretary. The other members of the section committee are Professors C. L. Hull, K. M. Dallenbach, C. C. Brigham, D. G. Paterson, and Herbert Woodrow.